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TEACH AND PREACH

By F. V. LARKIN, *Vice President*,
Director Mechanical and Industrial Engineering, Lehigh University

Three hundred years ago our forbears went to church with muskets primed. Then gradually they learned that maximum well-being came when some undertook to preach, some to protect, and others to provide. In the meantime we have evolved a great industrial civilization. The preachers of those early days sought out pure truth. They analyzed, they formulated codes, they taught adherence to sound principles, and they demonstrated fully that thereby men progress to fuller, happier lives.

Success encouraged brilliant offspring of this group to broaden out the scope and seek the truths which they had reason to believe lay hidden in the natural sciences. And when systematic effort was applied, this new and undeveloped field yielded rewards so fascinating, so rich in recognition, social place, personal satisfaction, that young energetic minds were fired with a gripping zeal to undertake careers of scientific achievement and accomplishment.

Just when or why this younger offshoot of the preaching group came to be known as engineers I do not specify. But here we are, happy within the great realm of industry, and quite neglectful of those other groups whose functions are to protect and to provide. We love our life—seeking and finding truths—putting them into commercial form, utilizing them to provide for the common good, and enjoying the rich reward of an ever-rising standard of living. Our philosophy is based on the biological inequality of men. We organize in such a way that the abilities of one dovetail with the shortcomings of another. We arrange our functions such that each uses only the talents which in him are superior. Thereby a maximum excel and scientific progress sweeps ahead.

And while we bathe our souls in the invigorating self-created stream of scientific achievement, we all but utterly neglect the other groups. Carelessness, complacency, selfishness take root in us; bitterness, envy, greed grow up in them, urging the use of their protecting service-implements in what to them appears a justifiable self-defense. Thus periodically the march of science has been interrupted to give attention to some social ill.

Brother engineers, when shall we learn that science and democracy are made from wholly different things, that democracy based on the political equality of men can never rise above the mean, that it is our duty to apply some of our talents and our time in the search for social truths, establishing, arranging, utilizing them in such a way as will distribute all our scientific good in accordance with the abilities of men to contribute and to prosper under it?

EFFECT OF ENGINEERING SCHOOLS ON THE SOCIAL AND ECONOMIC LIFE OF EUROPE

By WILLIAM E. WICKENDEN,*

President, Case School of Applied Science

The character of institutions, like that of individuals is largely conditioned by heredity and early nurture. The genius of America has found its most characteristic expression in the establishment of individual enterprises with a minimum of social guidance and restraint. Our early industries, scientific foundations, schools of technology and professional organizations all sprang from a society under the spell of pioneer traditions and one which fervently believed that the best service to the common good was to help the aspiring individual to get ahead. To the fathers of a century ago, that government was best which governed least, consistent with public order and defense. We are now in the midst of a broad socializing movement which proposes to bind our once isolated enterprises together by groups and to knit up these strands into the fabric of a planned society. We here are concerned with the part which engineering education and research may have in this changing social order. It may be pertinent to consider briefly what the schools of engineering have contributed to the common life of typical European countries, under a social philosophy more consciously collective than our own has been in the past. For this review we may select France, Germany, and Great Britain, with briefer references to Italy, Switzerland and Sweden.

Systematic education for the technical professions had its beginnings in France and was more highly developed there than in any other country until the middle of the last century. From the beginning the French schools have had clear and specific aims—to train men for certain functions in government and in industry. In consequence they have been little touched by welfare ideals or by the vague, democratic "educationism" so much in vogue in present-day America. Whereas the ancient universities of France had grown up under the shelter of cathedrals and abbeys and were devoted largely to abstract learning, the first technical school was established in the office of the chief engineer of the royal corps of bridges and highways. It was an orderly substitute for what had

* Presented at the 40th Anniversary Meeting, S. P. E. E., June 26–30, 1933, Chicago, Ill.

been a casual apprenticeship, and the original aim was quite as much to familiarize the students with the routine and standards of the corps as to ground them in scientific knowledge. The need of the latter, however, was immediately apparent. Learned savants were called in to teach the basic sciences, while the arts of design and construction and the technic of exploitation and operation was taught by distinguished practitioners. Oral teaching was supplemented by assigned projects and by experience in the field in the long vacations. This scheme worked out 150 years ago is still the dominant plan of French technical education.

By the time of the Revolution each of the technical services of the State had its own training school. To avert their disruption, it was first proposed to combine them into a great school of public works, but this plan was soon abandoned by creating the Ecole Polytechnique as a common source of preliminary scientific training and recruitment. At once the new institution drew to its faculty the most creative men in French science and became the most renowned center of scientific teaching of the period. An elite among the young men of France began to be attracted to the engineering profession and to the services of the State. As it was necessary to limit admissions to the number for whom places could later be found in the schools of application, a rigorous competitive system of examinations was introduced. Furthermore, the intellectual discipline of Ecole Polytechnique was so rigorous as to discourage all but the ablest and most persistent of aspirants.

Napoleon crippled the universities of France and bestowed his favors on the technical schools of higher and lower rank. He fostered great public enterprises and raised the engineering profession of France to a commanding prestige, but its talents were drawn almost entirely to the service of the State. While continental Europe was exhausting itself in the Napoleonic struggle, Great Britain employed her freedom and isolation to build up her industries and to acquire a dominating position in world trade. With the collapse of the Napoleonic system in 1815 the supremacy of England, gained through private initiative, stood out impressively. France sought to recover lost ground through the promotion of private industry and found itself handicapped by having no great center for the training of civilian engineers. The State had drawn all talents to its service, and left industry to shift for itself. Private enterprise took up the task of creating a great Central School of Arts and Manufactures, which borrowed much of the scientific discipline of Ecole Polytechnique and added an encyclopaedic treatment of industrial technology. Ecole Central achieved a brilliant prestige from the start and drew to itself students from a large part of the world. Its formative influence as

a school of technology spread throughout Europe and was directly felt in America through the model which it afforded to Rensselaer.

France held an unchallenged leadership in technical education down to 1850, only to lose it gradually to Switzerland and Germany, as her own system became more and more ingrown. The State had made technical education its monopoly, putting its own interests first and leaving industry largely to shift for itself. It had centered all its efforts in Paris and neglected the provinces. It had concentrated its resources on a selected elite and neglected the great rank and file of moderate talents. It had raised the engineering profession to a high prestige, but had made it very difficult of access. It had created notable training schools, for specific services, but done little or nothing for the sustained nurture of the technical sciences through research. It had exalted the teaching of design and left the experimental processes in comparative neglect. Local and private initiative finally took up the task of providing for the developing needs of the country and has rounded out a fairly effective national system, including a flourishing group of so-called institutes affiliated with the provincial universities. In the meantime French technical education had passed from its early phase of world-wide leadership into a self-contained phase, effective in providing limited but a distinguished leadership for her own public and private enterprises, but not otherwise of great social significance either within or beyond her borders.

Leadership in technical education began to pass from France to Switzerland and Germany about 1850. France had early set her hand to the task of technical education in order to assure the recruitment of an elite of engineering talent for the service of the State. Aid to the upbuilding of industry was more or less an afterthought, and has only lately become a primary consideration. When, at the end of the Napoleonic period, German statesmen began deliberately to reshape the old agricultural states into the modern industrial empire, they turned to technical education and research as the means of furthering national destiny. Capital for the expansion of industry was scarce; as the states could not create it, they turned to the creation of skill and enlargement of knowledge as the remedy for the economic ills of the period and the guarantee of future security. A century later, a stricken Germany in the aftermath of the War's disaster, presented a striking parallel. She turned again to technical education and research for her means of salvation.

The German technical schools of a century ago were in reality higher trade schools. The technical sciences had been spurned by the older universities and the *gymnasium;* accordingly it was necessary to go back for a beginning to elementary school foundations.

Here and there certain schools, under the patronage of influential officials, added more advanced departments. In time new types of secondary schools teaching the *realien* or modern branches were created to prepare for these higher courses. Beginning about 1860 there was a well organized movement, headed by the Verein Deutscher Ingenieure, to raise certain of the polytechnic schools to full equality with the old-line universities, which came to its consummation about 1900 The result of this evolution has been to fix German technical schools, with few exceptions, at four clearly defined levels: (1) technical universities for higher professional training and research; (2) higher industrial schools for the training of technicians, designers and builders; (3) middle industrial schools, for the training of industrial supervisors and the higher grades of craftsmen and (4) continuation schools training graduates of the elementary schools for specific industries and trades, in connection with apprenticeship. The technical universities, of which eleven are polytechnic and two monotechnic in character, are all under the ministries of education of the several states of the Reich. The intermediate and lower schools are in part under state, municipal, industrial and private auspices. The states, however, exercise either complete or partial control through their ministries of commerce and industry. This simple division of the field, with the clearly defined level and aims of each school fixed by relatively uniform official regulations, greatly simplifies their relations with the industries and the public.

The technical universities are the chief arm of the state for fostering the progress of industry. German industry is conscious, to a degree unknown in America, that its destiny is collective. It will survive or perish as a whole, and with it, the German state and, for that matter, modern German civilization. Competition between concerns is keen enough, but the deadliest competition is not between individuals, or firms, or for that matter between whole industries, as it is with us, but between nations. The survival instinct turns the German to collective measures under the State just as naturally as it turns the American to individual enterprise. Instinctively the German mind feels that the highest possible service to industry will come by seeking out the most fertile and creative men, by providing them with the most complete resources possible, by associating them together in the highest type of State institution, and by encouraging them to devote their entire energies to the advancement of the technical sciences and arts for the common benefit of all. American tradition, under our doctrine of private enterprise, has tended to a large degree to reserve the services of fertile and creative men for private corporations and to leave to our public and semi-public institutions second rate men.

together with individualists and idealists which industry finds it difficult to assimilate. Happily, this phase of our public economy is rapidly passing.

The German technical universities have an undisputed claim on the ablest men in the technical professions. I was repeatedly assured that any engineer will unhesitatingly leave a high post in private industry for a professorial chair at the call of the State. Such a call is virtually a social mandate. Professors have preferential treatment in salaries and perquisites on a par with judges of the highest courts; they are given great freedom; their sole duty is to advance the arts and sciences which they profess; research and technical consultation on advanced problems are given high importance as means to this end; and teaching is but one of several activities included within this major task.

The major research work of German industries is done in technical universities and public research institutes rather than private laboratories. The professors are in constant touch with industry in the areas of their most advanced problems. As a practitioner, the professor is not a competitor to firms or individuals—he is a consulting engineer to the engineers of industry. The result is that German laboratories are full of equipment and of research projects supplied by industrial concerns and the undergraduate student often has to take his chances on finding apparatus free for normal instruction. Industrial associations and the Verein Deutscher Ingenieure are also active in promoting researches and special projects practically all in university laboratories.

To assume that teaching is a minor function in a German technical university would be quite unwarranted. The real point is that teaching is done in an environment dominated by efforts to advance the art on its highest levels. The technical universities alone would constitute an inadequate scheme of technical education. Were it not for the higher industrial schools, which are teaching institutions predominantly, many a youth would be ill-served. These schools require at least two years of industrial experience before admission and maintain the closest contact with actual, current practices in their respective fields. Most of them operate on a forty-four hour week and a forty-week year, and cater to the type of young man who is a "learner," rather than a "student."

Of special interest to the American observer is the overall coordinating agency which brings together all parties interested in technical education, the German Commission for Technical Education, known colloquially as the Datsch. Established in 1908 on the initiative of the *Verein Deutscher Ingenieure,* its membership now includes more than forty societies and associations as well as

a large number of industrial concerns. Its field of interest covers the relation of technical education to general education, vocational guidance, university education for engineers, education for industrial supervisors and technicians, the training of artisans and continuation schools. It publishes much illustrative and guidance material, and issues the principal journal on technical education in the German language. The Datsch is without doubt the most influential non-governmental agency of coördination in the entire area of German education. Apart from its sales of educational charts and materials, its support comes chiefly from the member industries and associations, whose subscriptions range from 3 to 10 pfennigs per year per employee or member.

As France is the chief exemplar of technical education impressed into the direct service of the State, so Germany is outstanding for her fostering of industry as a form of national destiny. To this the eminent French sociologist, Charles Gide, bears witness:

> "It is technical education, patiently pursued, conscientiously assimilated, which has been for Germany an arm more powerful than the spirit of enterprise of the English and the artistic feeling of the French. She owes to it her admirable commercial and industrial advance."

A century ago industry was held in low esteem in Germany. Among the youth of the country state employment was everywhere desired. This state of mind was progressively reversed, and after the late war the tide set toward industry in a veritable flood. Enrollments in the divisions of chemical, mechanical and electrical engineering doubled, and in some cases quadrupled. Virtually all the flow of man-power which had gone into the officership of the army turned toward engineering and Germany found herself with a rapidly mounting surplus in the technical professions, which of late has risen to nearly 200,000 men without prospect of suitable employment. Five years and more ago the reverence for American methods of mass production amounted almost to worship, but efforts to adopt these methods without the support of mass markets proved disappointing and present observers are noting in the Nazi movement signs of revulsion against extreme forms of industrialism and a homesickness for the traditions of the older Germany of a century and more ago.

Germany, beyond question, has done more than any other country to invest the professorship with prestige and public influence. She more than any other country has sought in research to find compensation for meagre natural wealth. More than any other country she has made her technical universities and academies not mere training schools, but centers of far-reaching scientific nur-

ture. The same is true in much the same degree of Switzerland, Belgium, Holland, Italy, the Scandinavian countries, Czechoslovakia, Austria and Hungary. To an American observer, the relative lack of concern for the welfare of the individual student, and the preoccupation with the problems of national economy is striking throughout all of continental Europe.

Switzerland is perhaps the most notable example of all of deliberate economic selection on a national scale, achieved largely through technical education. Physical resources being extremely limited and completely exploited, efforts to provide a good living have been turned into the channels of fine mechanisms, where the maximum of intelligence and skill may be concentrated on the minimum amount of material, at low import cost and high export return in foodstuffs and fuel. Sweden ranks with Switzerland in her intelligent concern to make her limited but valuable resources yield a satisfying life to the largest possible population. Teaching and research alike emphasize refinements in the wood and iron industries, strive for economy in the use of fuel and water power, promote domestic as well as industrial use of electricity and seek for long life and maximum reclamation in the use cycles of imported commodities.

The fascist régime in Italy has vitalized the engineering schools from a fairly obscure and neglected arm of the educational system into new life and vigor. The physical renovation of the country, the intensive development of resources, the up-building of the merchant marine and the outreach for industries of refinement and precision have become the absorbing interest of the schools. Direct integration with the national program of development has provided money and influence for modernization of plant and equipment, so long denied by the old régime.

In passing from Continental Europe to Great Britain one observes a striking contrast in all that concerns technical education. The motive of the early British efforts was that of personal welfare, to assist aspiring artisans to rise in the world by evening lectures and study. Full-time schools were late to arrive; they developed against heavy odds of tradition and have never attained the status of complete agencies of professional training like the continental schools for engineers. Chairs of civil engineering were established in London and Glasgow in 1840, a Royal College of Chemistry in London in 1845 and a Government School of Mines in 1851. These remained isolated and scattered efforts until 1880, when the university schools of engineering began to develop with greater vigor, a movement which has assumed significant numerical proportions only since 1900.

This belated development of higher education in applied science

reflects a deep traditional faith in practical activity and a distrust of theoretical science as a suitable training for engineers. The early engineers, Newcomen, Smeaton, Watt, Telford, Stevenson and their contemporaries, were all working men. trained by apprenticeship, who had gained some supplementary scientific knowledge by their own efforts. Under the middle-class, laissez-faire philosophy of the industrial revolution, it was assumed that a succession of similar geniuses would arise, with perhaps a little help from evening classes in scientific subjects. The workingmen's colleges and mechanics institutes endeavored to fill this need down to the middle of the last century; following their decline government subsidies were offered as a stimulus to "science and art" classes under private auspices. A troup of so-called polytechnics were created under charitable auspices in London in the late 60's and early 70's to offer popular technical education and welfare services. Severe trade depressions in the 70's and 80's drew attention to the inadequacy of the voluntary evening classes, stimulated by grants based on successful examinations.

The agitation led up to a series of Parliamentary acts which enabled the local education districts to establish technical schools, and set aside certain excise revenues known as "whiskey money" for their support. These local technical institutions, of which there are now more than 250 in Great Britain, supply by far the greater part of the higher and intermediate technical education. These institutions and the universities overlap and interweave to some extent, but for the most part there is a distinct and effective division of functions between them. The universities have great independence and are uncompromisingly devoted to higher intellectual pursuits, placing a large emphasis on research and training a limited body of men for work in engineering which requires a high standard of scientific attainment. Each local technical school is the apex of a district unit of the general system of public education. Its program is closely linked with the daily interests of the local population; most of its work is for employed men and women, and is done in part-time or evening classes. Half the support comes from the national government and half from local taxes and a close inspection is maintained by the national boards of Education, both in England and Scotland.

Nine-tenths of British effort in technical education is thus concentrated on employed persons and the bonds with industry, through the local educational authorities, are exceedingly intimate. Both parties have come to recognize that evening instruction, even at its best, has severe limitations and there is now a vigorous movement backed by the national authorities for a wider introduction of part-time day courses to which employers may send their engi-

neering apprentices for two or three half-days a week. The number already so enrolled exceeds the total of university enrollments in engineering by more than half and is increasing rapidly. In the best informed circles, both industrial and governmental, this movement is believed to hold the main highway of educational progress.

The universities, as has been implied, do their work in a more detached spirit. The professors are professors by career. Few of them engage in remunerative practice, but virtually all are active in research. British research, however, appears to be of a more gratuitous character than German, and not so closely related to the immediate problems of industry. However, the professors are very active in the research councils of the several industries, where many of them represent the national institutions of engineers. The scholarly qualities of these professors are outstanding, in no place seriously rivalled among British engineers in industrial practice.

The university schools of engineering are by choice small and intimate institutions, modestly equipped, fundamentally scientific in aim, little occupied with specialized training and fairly rich in the intangibles of British university life. A student body of 150 to 200 men is quite representative. Industry and university grew up in separate compartments of British life and the barriers are not yet fully levelled. In recent years probably not more than half of the 600 men who come from the universities with degrees in technical science—as compared with more than 10,000 in the United States—have found suitable employment within the first year. Employers generally turn to the universities only for men of exceptional talent and cultivated personal backgrounds. The evening and part-time courses of the local technical schools supply a practically unlimited reservoir of rank-and-file technical personnel. It would seem that British industry has not yet been separated from its traditional trial-and-error philosophy, nor has it accepted with any wholeheartedness the modern heirarchy of scientific brains. This indeed may prove to be the weakest link in the armor in the world struggle for trade in which Britain must fight for her life. As Stanley Baldwin has warned—"the future rests with the nation which is most successful in harnessing science to industry."

The characteristic differences of purpose and ideals between our own engineering schools and those of Europe may be more clearly understood when one remembers that in the space which we are able to afford to the average American, France must provide a living for five, Switzerland for six, Germany and Italy each for nine, and England and Wales together for seventeen. None of these countries is more richly endowed per square mile than our own or enjoys as nearly balanced resources—most of them, in fact

much less so. Furthermore each of them had an old and mature civilization, a relatively crowded population and a permanently stratified society before the engineering profession emerged, or schools were developed for its training. Our engineering colleges were created in a new world, where men were scarce and each was to be made the most of, but where resources were seemingly inexhaustible. These conditions are changing. In the older sections of our country, we too are beginning to feel the crowding of population and the thinning of resources. The common concerns of our society are assuming greater importance relative to those of the individual. More and more our engineering faces the problem of a good life for the whole people. Our concern for the welfare of the individual student should not grow less, but our share in the shaping of national economy must increase as America comes of age.

ENGINEERING EDUCATION AS AN APPROACH TO CULTURE *

By WILLARD E. HOTCHKISS

President, Armour Institute of Technology

It is indeed a pleasure to convey to the members of this Society greetings from Armour Institute of Technology, and to extend any courtesies it is possible to extend in connection with this meeting. I do not feel very responsible for them myself, because I have an efficient staff which has done whatever has been done, and I am unable even to claim credit for the staff because it was at the Institute before I was.

It is a very happy coincidence, as our Chairman so thoughtfully pointed out, that we have the opportunity to celebrate our own fortieth anniversary in connection with the retrospect of the forty years that have elapsed between the World's Columbia Exposition and A Century of Progress.

About two weeks ago my former colleague at Northwestern University, Baker Brownell, called me up and asked me to participate in a dialogue with which he proposed to conclude his course in contemporary thought next year. He was proposing to have Dean Hibbard of the College of Liberal Arts at Northwestern talk informally about the importance of liberal arts education as a preparation for life, and he wanted me to talk about engineering education as a basis of general culture. Having accepted Professor Brownell's invitation, I trust you will not accuse me of turning my part in this morning's exercises into a rehearsal if I call this talk Engineering Education as an Approach to Culture.

There is a tendency to think of culture, when the word is placed alongside of the word education, as something impractical and hifalutin, something one takes and promptly gets out of his system. No such ideas come into our heads when we talk about agriculture, horticulture, viniculture, or any other kind of culture. I believe we are gradually discarding the thought in connection with education, but a certain traditionalism in so-called cultural curricula has given enough plausibility to the idea of culture as something largely ornamental, so that it still persists.

When I speak about engineering as an approach to culture, I

* Presented at the 40th Anniversary Meeting, S. P. E. E., Chicago, Ill., June 26–30, 1933.

am thinking of culture as a development of personality, a discipline of the mind and the emotions, and a preparation for living and doing one's work in society. We do not know just what sort of a society it will be in which this generation of students will do their work, but it bids fair to continue being a changing society, and one in which engineering will be tied in with nearly every phase of living. It bids fair to be a society which will make heavy demands on ability to adjust oneself to new conditions, a society in which mental and emotional flexibility and capacity for growth will be at a premium. To live well and serve well in the society of the on-coming generation, it will be essential to possess a mind and a character so disciplined that the stability of their foundations will not be impaired by changes in the superstructure of living. From this standpoint, it appears to me that engineering education, adapted, rounded out, and supplemented to prepare engineers to meet the demands which those who are moderately successful already have to meet, will furnish about as good an approach to culture as can be found.

During the past generation we have been trying a vast educational experiment. We have been bringing thousands and thousands of young people into our universities, and have exposed them to something that we have labeled education. They have been exposed, but we have a suspicion that in too large a number of cases the serum did not take. We are doubtful whether a large number of graduates have learned how to do a close job of thinking. We are not sure that enough of them know how to find facts and apply them. We are concerned about their ability to recognize truth. We wonder if civilization is safe in their hands. We are convinced that we must tighten up all along the line. Even when we make allowance for our own dizziness, for the sense of anxiety engendered by the speed at which our generation has moved, we are still sure that something must be done to improve education, and we are resolved to make the attempt.

When, in preparing to move forward, we take account of stock and look for something in our education which has the merit of having held students down to earth, we find that in this regard, whatever its faults, engineering education has made the grade. Speaking by and large, engineering education has kept the student's mind on the track; it has encouraged habits of passing from cause to effect, of discriminating between the essential and the unessential, in the solution of problems. Better, perhaps, than almost any other phase of education, it has developed the student's instinct of workmanship. These are excellent foundations upon which to build; they are fundamental to education of every sort.

The things about engineering education in the past which have

impressed the outsider as shortcomings have been associated with the idea that it is something ultra-practical, even a bit low-brow, and we have thought of it sometimes as definitely excluding things which the man in the street is accustomed to think of as culture. The trends of industrial and technical development have placed emphasis on getting things done. The highly trained technician is a man who can do things, and there was no lack of people to tell him what to do. While the voice of the engineer has not been silent in council, his advice and guidance for the most part has had to do with technical problems rather than with basic policies, and his own training and traditions have not inclined him to assert leadership as a social philosopher. In the cases in which engineers have asserted such leadership they have sometimes lacked the background for grasping the social problems with which they have tried to deal. All these circumstances have come about naturally from conditions is which engineering has developed.

We do not need to be unduly critical about the inheritance of the past; the task is rather to recognize the job for the future and to go ahead and do it. The thought expressed in the subject of this meeting, the place of engineering in the social life of the community, contains as I see it, the viewpoint from which engineering education may in the future build on foundations already laid, both professionally and as a preparation for living.

I referred just now to uncertainties concerning the kind of a world in which our graduates of today and tomorrow will live. Occasionally someone comes forward with a thought that the day of rapid technical change is about over, but no sooner is such a view put forth than some revolutionary discovery or invention appears to refute it. When I was an undergraduate in college we were sometimes referred to a book written some fifteen years earlier which developed the theme that the day of technical change was drawing to a close. The author pointed out that illumination by gas, replacing the kerosene lamp and the earlier tallow candle, had made man supreme over darkness. He stressed the development of steam power and refinements in its use which had built up a factory production of incredible efficiency and volume, facilitated rapid exchange of goods and ideas regardless of distance, and made it possible for human beings to go at will and quickly by land or sea from one end of the world to the other. The miracle-working telegraph, he noted, had met all conceivable requirements which urgency or emergency could advance. Considering these and other appointments for carrying on a complex and comfortable civilization, he said that further important technical advances were impossible to conceive. Within a decade after this book was published, its prophecies were cited merely as quaint specimens of a seer's blindness.

A somewhat different type of prophet sees the tempo of technical change continuing and accelerating its pace in such a way as to create problems of adjustment which society cannot solve. It must be confessed that events during the past four years give some color to this kind of apprehension, but on the other hand, a survey of the record reveals that technical advance has been proceeding through periods of acceleration and retardation ever since the first machine came into use. Society always has had and probably always will have the task of reorganizing itself from time to time in order to safeguard the benefits of the techniques which it creates, and to minimize the harm which these techniques may do to individuals who have practiced other techniques and who are unable to shift.

There is little prospect that technical advance will cease. When we view the present scene and contemplate the problems upon which scientists and engineers are now at work we can easily predict a long era of engineering triumph. Moreover, I cannot conceive that the hard experiences of this depression mean that technology will permanently run civilization off the track. But there is obvious need for society to take account of human stresses and strains similarly as physical stresses and strains are considered in the structures which engineers design. In the interest of civilization, the impact of technical changes and industrial upheavals upon individuals and groups clearly needs to be softened.

To place itself in a position to render maximum aid in balancing technical and social progress is the outstanding cultural problem with which engineering education is concerned. Even if we assume that the vast social, political, and economic experiments being tried all over the world are doomed to fail, we still have the task of preparing engineering students to live in a society which, from all present appearances, is likely to be fully as dynamic as any society in the past.

The educational lesson to be drawn from periods of change and maladjustment is the need for a type of education which, from a professional standpoint, will develop in the individual the greatest amount of flexibility consistent with competence in some particular field. At the same time, the need is just as great from the standpoint of citizenship for developing a philosophy of living and an attitude toward society which will enable the professional engineer to make his full contribution toward humanizing the process of technical and industrial change.

In a civilization whose parts are as closely interwoven as are those of our civilization to-day, it is scarcely possible for any large percentage of practitioners in special fields to attain the highest degree of competence without considerable knowledge of the fields

upon which their own fields impinge. Bridges must not only be designed and built but they must be financed, and long before either the building or the financing can start studies must be made of the economic and social uses to which the bridges are to be put.

As I view that part of the total situation which comes within my range of vision, specialization has developed a capacity to do specific things, to design and make particular machines, which has outrun ability to coördinate, in the public interest, the operation of these machines. This fact creates a problem of social adjustment with which engineers are closely concerned. They can scarcely make their best contribution towards solving it unless they have a fairly rich scholarly background and a solid ground work of understanding upon which to base judgments concerning the wisdom of the projects with which they are associated.

The danger of superficiality when a professional school extends its work beyond its traditional borders must, of course, be recognized and met. Until recently I have been viewing this problem of the relation between engineering and other types of education from the other side of the street. When we were setting up a course of study for the Graduate School of Business at Stanford I started in by attaching an engineer to the faculty, and then the two of us sat down with Dean Theodore Hoover to work out a plan for injecting into the business course work calculated to give the students an appreciation of the important place engineering occupies in business administration.

Dean Hoover was extremely coöperative, and gave us free run of any of the engineering laboratories we were able to use. In laying out the work we started from the premise that just as an engineer who becomes a business executive needs to read a financial statement and to know what it means, so an executive educated in a business school or an arts college must know what an engineer is talking about when he comes in with a set of blueprints.

I must confess that stated in these elementary terms, this approach did sound a bit superficial, whether viewed from the angle of the engineering school or the school of business. I am aware also that any program for penetrating beyond academic frontiers encounters at once the wire entanglements of sequence and prerequisites. But the great obstacle to progress with any proposal looking toward integrating one field with another and with general education, I am convinced, is psychological, and it lies chiefly in the tenacity with which many specialists hold to their traditional reactions in respect to any intellectual effort of non-specialists. As some engineers see it, reading a blueprint or learning something about the behaviour of certain machinery and materials is a net loss for anyone who cannot design a machine.

Now, of course, some of us who are not engineers are sophisticated enough to know that not every engineer is habitually occupied designing machines. What is more important, everyone knows that intelligent people in every walk of life, specialists and non-specialists alike, require in the ordinary routine of living and doing their work a range of appreciation and understanding far beyond the confines of any one field of knowledge. It is the task of education, however specialized may be the superstructure, to lay foundations at the base which will permit of selection and balance in developing the range of understanding and appreciation best suited to the work the individual is to do, and the kind of life he desires to live.

The governing body at Armour Institute of Technology decided sometime ago that the curricula of the Institute needed to be revised in accord with the general point of view just stated. In approaching this revision we are assuming without argument that an engineer in the future is going to need a fairly broad general education, and that it is the duty of an undergraduate engineering school to provide him the opportunity to secure such an education. We are also assuming something which our engineering colleagues will accept but which some others may not, namely, that subject matter related to engineering may serve quite as successfully as a vehicle for general education—cultural education if you will—as it serves for professional engineering education, and even more effectively perhaps than numerous alternative materials ordinarily associated with general college curricula. This last thought is well stated in the pamphlet "Engineering: A Career—A Culture" put out by the Engineering Foundation last year.

Everyone must realize that whatever the educational philosophy from which revisions of curricula proceed, the practical problem of putting them into effect will encounter obstacles. Real and assumed indispensables to education in engineering and all of its specialties cannot be ignored. There are schedules to be adjusted, and there is a limit to the time and the energy which both teachers and students can put forth. Not only is there no room to crowd new subject matter into the curriculum without crowding other subject matter out, but the amount of subject matter in all of our engineering curricula probably exceeds an optimum cargo. In the interest of teaching efficiency and without reference to any new materials, it would seem that some of this cargo ought to be jettisoned. These are some of the practical difficulties encountered in trying to pour new wine into old bottles.

In approaching this problem we decided to integrate all of the various curricula of the Freshman year into a unified course, and we appointed a Dean of Freshmen to direct it. The Freshman

course as outlined would constitute an appropriate first year curriculum for any university or college, but since we are an engineering school, it is both desirable and necessary to provide the mathematics, science, and graphics which the students will require for their later engineering work. In order to meet at once the danger of unduly overloading the students, we decided upon a maximum of seventeen hours per week, not only for Freshmen but for all students, and we hope later, possibly next year, to bring the amount of required work down as low as fifteen hours per week.

With an integrated Freshman course and a seventeen hour schedule, the question of broadening the curriculum became one of deciding what new subjects should be introduced, how they should be taught, and where in the curriculum place should be found for them. The fact that all engineering graduates have something to do with business and with social institutions and that many of them become executives and public servants made it appear proper, if not indispensable, from the professional point of view, to include something about business and social institutions in engineering curricula. Moreover, it is believed that these subjects, if well taught, may be made especially fruitful from the standpoint of general education.

In addition to the subject matter which we may call by the general term "Social Science," it seemed necessary to strengthen somewhat and increase the required work in English. The problem in respect to both Social Science and English became one of seeking the most effective compromise between the maximum time which could be made available for these subjects and the minimum time in which they could be acceptably handled.

Before facing this problem we had to decide what elements in the engineering and architectural curricula could be omitted or compressed with a minimum of harm. Without discussing the arguments, pro and con, I will simply report that we decided to suspend so-called shops. The subject of shops has been expounded at length in the proceedings of this society. One of the reasons for taking this action was, frankly, financial, but besides this it was believed that our shops as previously conducted needed a thorough overhauling and a closer integration with some of the laboratory courses, and it was believed that this task could be best performed by closing them and making a new start.

Before providing for courses in the Social Sciences we decided that required work in English carrying a credit of two semester hours should be carried through the Freshman and Sophomore years. The result of all of this revamping yielded out of a seventeen semester hour schedule throughout the four years a total during the undergraduate course of fifteen semester hours available for

Social Sciences. Decision was made to allocate seven of these fifteen hours to the Freshman year and eight to the Senior year. The Freshman courses we are labeling "Business and Engineering Problems" in the first semester and "Social and Engineering Problems" in the second. We are calling one semester of the Senior course "Business Policy" and the other "Public Policy." The objectives aimed at in these courses are fairly clear. The purpose in the Freshman year will be to make the students aware of the framework and functioning of the society in which they live and the way in which engineering fits into that society. Coming at the beginning of his course, study in this field should add an element of appreciation and meaning to the more definitely professional work of the engineering courses than they would otherwise have.

In the Senior year students are thinking about getting a job and beginning work. The courses in Business Policy and Public Policy offered at a time when the student is concluding his professional preparation should have the effect of increasing the range of positions to which graduates may aspire, and of increasing his understanding of the work he will be expected to do in the practical world of which he is a part.

The task before us now is to find teachers qualified by training and interest to handle these courses, and to organize the subject matter in such a way as to give them maximum appeal and maximum effectiveness. We are hopeful, I think I may say confident, that our teachers of engineering subjects will coöperate fully both in the collection of material and in the interpretation of engineering projects in connection with this new work. We expect also that during the Sophomore and Junior years, in which no required work in Social Science is offered, they will find many occasions to call upon the teachers in the Social Science field to discuss economic and social aspects of some of the engineering problems with which students will be occupied.

If, as we now hope, we later succeed in reducing the required curriculum to fifteen hours, one result of a foundation course in Social Science during the Freshman year will probably be that some students will desire to elect other courses in that general field before they reach the Senior year. In addition to this, it is altogether likely that within the next year or two we shall follow the example of numerous other schools of engineering and set up an option in industrial engineering in which naturally more attention will be paid to business subjects than will be possible in the fields in which engineering techniques are of necessity more highly stressed.

The procedure which has to be adopted in introducing new elements into a professional curriculum tends to make the justi-

fication for these subjects the contribution which they are expected to make to the professional competence of students. It must be borne in mind, however, that there is of necessity no conflict between the professional utility of a subject, let us say like social and engineering problems or public policy, and its function, as subject matter for general education. This also applies in my opinion to nearly all of the courses hitherto offered in engineering schools. It is possible to pursue almost any subject as something entirely detached from the broader aspects of living. It is likewise not only possible but desirable to follow those subjects which are expected to contribute toward professional competence into channels which enrich the personality of the student, enlarge his appreciation, stimulate his intellectual curiosity and develop his capacity for close thinking. These are the earmarks of cultural education.

The persistence with which the academic mind has clung to the idea that somehow the words "cultural" and "practical" describe conflicting aims has tended to blur our thinking about the relation between professional and general education. If we accept as a cultural aim understanding of the universe, awareness of the universe to use a more guarded phrase—knowledge concerning the application of science to living should clearly be included under the term "cultural." Any course of study, no matter how direct may be its practical application to life, is cultural if it is taught and studied in such a way as to develop a student's mental power and build up his personality. Any course so taught and so studied is practical no matter how indirect its application may be.

In considering engineering education as an approach to culture I am thinking of an engineer not as a man who is called in by a group of capitalists and told to confine himself to designing and building a structure, but as a man who is a member of a planning board, whose judgment is valued in reference to the financial, social, and legal aspects of the engineering projects with which he is associated. He need not pose as a lawyer, an economist, a financier, or a social philosopher, but there is no inherent reason why many engineers should not also become proficient in some of these fields, and all of them should at least know what it is all about when the economic, financial, legal, and social bases of engineering projects are being discussed. I think we may go further than this and say that those who hope for leadership must regard themselves not primarily as belonging to a narrow craft or guild, but rather to that distinguished body of productive scholars who blaze trails of civilization.

There are those among us who speak of this machine age to disparage it; but whether the machine is an instrument of advance or of retrogression depends not upon the machine but upon those who determine the ends for which the machine is employed. This is a problem of human understanding, to advance which is the central purpose of all education. From this standpoint, engineering education cannot fulfill its most vital function in society except as it is regarded and developed as one of the approaches to culture.

POST-GRADUATION EDUCATION FOR ENGINEERING GRADUATES *

By V. M. FAIRES

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"Is more cultural training and a wider social outlook *needed* for industrial executives?" To this question put to industrial leaders by Professors Caldwell, Norman, and Younger, in a questionnaire the results of which are analyzed in The Ohio State University Study, *Economic Attitudes in Industry,* eighty-one answered "Yes"; five, "Not needed but helpful"; four, "No." Ninety per cent of those replying were unreservedly of the opinion that a wider social outlook by industrial executives was *needed.* Since this question referred to the training of *industrial* executives, and since other important studies (for example, the A. S. M. E. investigation into the economic status of engineers) indicate that many engineering graduates do attain administrative positions, the foregoing results might well be taken as a mandate to engineering schools to see that their graduates attain "a more cultural training and a wider social outlook."

The Armour Institute investigation confirmed the results obtained by the Ohio University study. Mr. James D. Cunningham in an article in the December, 1932, *Mechanical Engineering,* "The Armour Institute Development Plan," gives us the following statement which he says reflects the sentiment of some one hundred employers of the Chicago area.

> "This young man's vision [that of the engineering graduate] has actually been limited by his education. He does not express himself well; he has a good knowledge of engineering subjects, but he is incapable of generalizing from that knowledge; and not only does he know little except engineering, but he also knows almost nothing of the economic and social significance of engineering."

One has only to listen to the conversation of an average group of engineers, and this does not exclude the teachers of engineering, to discover an almost complete lack of interest in, if not a complete ignorance of, social, economic, political, and philosophical problems. It appears that not only are many engineers uninformed but that others actually belittle the importance of problems of humanity,

* Presented at the 40th anniversary meeting, S. P. E. E., Chicago, June 26–30, 1933.

assuming toward them an uncompromising and impatient attitude, born, no doubt, of a college-bred contempt for courses which as students they dubbed "bull courses." There is a widespread feeling among engineers, a feeling which happily has abated during the last two years, that the social sciences are inferior to the technical sciences. The training these engineers have received in the so-called exact sciences has somehow or other developed in them such a scorn for those fields of learning wherein delicate points of philosophy and logic are the life-blood that many engineers feel that thoughts not expressible with mathematical precision are worthless. Because the experts themselves hold conflicting opinions, our graduates often feel that no one knows anything about social subjects, and that, therefore, their notions, often a product of whim, are as valid as those of the expert. Or, if they are not cocksure, they sometimes go to the other extreme believing that since the experts with a vast supply of knowledge cannot agree, there can be no hope for a tyro, and forthwith become resigned to ignorance. Our engineering graduates have not been taught to seek knowledge in fields other than engineering. In fact, they leave college completely unaware of the importance of a liberal education—unaware that they have not been prepared by their college curriculum to discover the internal values of life which come as a reward to those vitally concerned with the problems of mankind.

Instead of promoting intellectual curiosity throughout life, many engineers and engineering teachers stifle it by smug assertions that engineering education is the best education to fit one for life. I have been guilty of thus rationalizing. It has come to pass, I believe, that sometimes at meetings such as these, we have naïvely justified our own education by insisting that it is the most vital of all, reasoning that this is the age of machines, machines which all educated people ought to know and understand. I wonder whether this rationalizing is not a defence of our conservatism, our resistance to change.

When our engineering graduates emerge upon the turmoil of the world to-day, they are nonplussed by conflicting admonitions. They must save and be thrifty if they are to succeed; yet they must spend to keep our industrial machinery turning. They must go in debt to get rich; yet they are told that a towering unsupportable debt structure did its part in plunging us into our present plight. They are told that we must protect to the utmost the rights of property, but that we need inflation to ease the burden of fixed debt. They are told, further, that the government must contract its budget and ease the tax burdens, but that high-powered spending by the government will launch us toward prosperity. They are told that we must invent more machines and improve the efficiency

of production so as to increase national wealth, but that improved machines and production methods throw men out of work and thus create poverty. They are told that a higher tariff is necessary to protect our industries which provide jobs for native citizens, but that high tariffs stifle the free exchange of goods thereby producing unemployment and starvation. Lacking reliable knowledge, the student and graduate must obviously be disconcerted in face of these and so many other paradoxes.

Furthermore, we must face squarely the fact that the influence of home and church is waning. Mr. Hoover's Research Committee on Social Trends made the following observation: "Of the great social organizations, two, the economic and the governmental, are growing at a rapid rate, while two others, the church and family, have declined in social significance, although not in human values. . . ." While the regulatory influences of these once powerful agencies, church and home, diminish, what are we as educators doing to provide something to compensate this loss? We have the obligation, whether we want it or not, of creating a background from which our graduates may construct a suitable philosophy of life. They are, therefore, entitled to enough philosophy and logic to prepare them for independent reflection—independent reflection upon the changes which our civilization seems to be undergoing. Possibly these changes will not be extreme within the lifetime of our present graduates, but whatever the changes, intelligent understanding will be impossible without the lessons of literary masterpieces, of history, of sociology, of psychology, of philosophy, of political science, and of economics. The foregoing remarks suggest a few problems which in one form or another will trouble all of our graduates; yet these men possess no foundation of organized information from which to reason—at least none supplied by the technical curricula.

Government is headed toward more intense regulation of what previous generations considered private affairs. Our graduates know little or nothing of the experience man has had with governmental regulation of industry. They know nothing of the attendant success or failure of various governmental attempts to mold the organization of society, much less of the reasons for the resulting success or failure. Thus, they are at the mercy of the demagogue and the newspaper headlines. They are not critical for the simple reason that the educational process to which they have been subjected does not encourage a critical attitude. Although there are plenty of controversial problems in engineering, the student seldom meets them during his school days. In the nature of things, we must spend most of our time in trying to get the student to learn and understand as many of those more or less fixed truths of engi-

neering as we can. Ordinarily he is right or wrong, which fact may account for his swallowing whole any plausible statement in another field. Now the kind of study that will make him critical, that will make him suspend judgment, is one wherein well-founded differences of opinion exist. He must be made acquainted with ideas about which there exists controversy—for such ideas are the substance of life.

We are duty bound to help the student to reason intelligently on social affairs, and if we are to take pride in our graduate, we must help him achieve a background in the humanities and social sciences. We have given him a basis for sound thinking about matters of engineering; it is just as important that we provide a basis for sound thinking about *life*.

It is the order of the day to question our social organization. Mr. Hoover's Research Committee on Social Trends reported:

> "The committee does not wish to assume an attitude of alarmist irresponsibility but it would be highly negligent to gloss over the stark and bitter realities of the social situation and to ignore the imminent perils in further advance of our heavy technical machinery over crumbling roads and shaking bridges."

When government reports begin to speak of a shaky foundation for our social order, it is assuredly time that the educators (educators of the country's future leaders by our own admission) recognize the conditions and begin to act. And by acting, I do not mean that we should bury our heads in the ground and protest, "The foundation isn't shaky. Don't believe it." As a matter of fact, we are not obliged to pass any judgment on the matter whatever. We are obliged to provide these future leaders with enlightenment and prepare them for any change that may occur and acquaint them with the forces acting to bring these changes about. Is it an exaggeration to say that our engineering graduates know of only one social order, our own, and that they do not even realize our own is in a state of flux?

Assuming that more cultural training and a wider social outlook is needed for the engineering graduate, let us examine possibilities for correcting the deficiency.

Exhortation to the student by the engineering teacher seems ineffective. Charging him to take his language, history, and economic courses more seriously, recommending that he read avidly before and after he leaves school—such admonitions have had little effect in the past. If *all* engineering teachers united to give exactly the same advice (a Utopian idea), many graduates would be undoubtedly frightened into a serious study of social questions, and that pest of education—the classification of subjects into major and

minor ones—might be relegated to our more ignorant past. Even forcefully impressing the student—assuming for the moment that it could be done on a large scale, a highly improbable matter—even forcefully impressing the student that the whole matter is a question of self-interest would be insufficient. Results are not immediate, and cause and consequence in life are too intangible for positive identification. Consequently, no number of resolutions to preach and reform made and unanimously adopted by teachers will correct the faults with which we are confronted. Moreover, the graduate needs guidance in new fields as surely as the undergraduate needs to be led through an engineering curriculum. The responsibility for providing this guidance, I believe, rests at the top of the administrative division. Here belongs the initiative.

The first attempt at positive corrective action might be a change in the curriculum. But few engineering teachers see their way clear to replace technical subjects by others taken from the arts school, although the Armour Institute of Technology is doing this very thing. In schools wherein military training assumes the proportions of an academic major, the typical curriculum contains practically a minimum of technical subjects. In some of these schools, the student "elects" to devote a total of twenty-four semester credit hours to military technique. To be sure, schools without military training might use this twenty-four credit hours for liberalizing studies if they were willing. But apparently few are willing. In any event, we may conclude that this process of substituting liberal arts subjects will not proceed rapidly, and in no case will the liberalizing work thus taken be effective as long as the engineering student looks upon such work as inferior in importance and degree to his professional work. College life, at best an artificial life, does not always stimulate in the undergraduate a scholarly attitude toward studies so full of the realities of life.

The increasing of the engineering curriculum to five or six years has been offered as a means of giving the graduate a "wide social outlook." If perchance the student, by two years of pre-engineering work in the arts and science school, finds himself interested in the social and economic aspects of our civilization, there is the likelihood that this interest during the next three or four years of technical education will become dormant never to waken again. Hence, there is no good reason why we should make an effort to imitate the medical school in this respect. If I have observed correctly, pre-medical education does not accomplish for the doctors that which we must accomplish for the engineers, at least, for engineers intellectually fitted. As a matter of fact, our problem is quite different from that of the medical schools. When the medical graduate begins to practice, he may be immediately subjected to

vast responsibilities. In some situations, just a little more maturity in the physician may mean the difference between life and death for the patient. Thus, merely delaying the date of graduation of the medical student may be justified. But the only excuse we can offer for keeping the engineering student in school longer is that we should like for him to take some conventional humanistic courses which will be of doubtful value, coming as they do during immaturity. Industrial employers tell us that four years of training is enough to provide a technical foundation. Most engineering teachers agree that four years is ample time in which to give the ambitious student a reasonable knowledge of the fundamentals of engineering.

Since a consideration of the foregoing plans reveals their inadequacy, I suggest that we find a solution that surmounts our difficulties. My proposal is briefly this: That we should offer the young engineer a definite *incentive* to study non-engineering subjects after he graduates. Furthermore, heretical as it may sound, I propose that the incentive be a B.A. degree granted after the completion of the proper courses taken by correspondence.

Those studies in which engineering graduates are deficient would not be difficult to administer by correspondence. Various courses of study in economics, history, sociology, philosophy, and other fields could be arranged in accordance with the facilities of a given college or university. The administrators of the institution must determine the content and extent of the work, although I believe that all schools should conform to certain minimum requirements.

I am aware of the existence of many difficulties, most of which are owing to tradition. It is necessary for us to overcome our impulse to belittle education by correspondence. It will take time and effort to convince the authorities with their veto power that the results to be achieved will compensate for the sacrifice of a few of those requirements for a B.A. degree bequeathed us by our forefathers. Of all people we should be able to break away from tradition if the exigencies of the situation demand it.

Upon consideration, one finds the aspects of the proposal not so radical as they first appear. We shall be dealing with men who have proved themselves, having already obtained a B.S. degree in engineering. If each institution cares for its own graduates, it will be dealing with men who have satisfied the residence requirements. Those schools which already have correspondence departments would be placed to little extra expense for administration. It may take a brave school to inaugurate the plan, but those institutions which do so will, in the course of time, possess a powerful attraction to the better type of student; and, if the results of the questionnaire first quoted in this paper mean anything, employers will

not be unmindful of the advantages accruing from employing the graduates of an institution which refuses to forget that its function of educating does not cease with the awarding of a diploma. Another advantage: The university or college would keep in closer touch with a section of its alumni, who might cease to feel that the usefulness of their alma mater is limited to being a place to return to for a rousing spree.

If the advantages of this plan of post-graduation education were solely in favor of the employer and the school, I should not be so much concerned about the matter. The more important benefits will be to the individual, and hence to society. If we desire some day to have an educated society, we must teach our students to continue studying through life. The road to this objective might well be paved by this plan of post-graduation education.

All points in this program indicate that the work will possess many virtues not found in resident study. The study of those intrinsically humanistic courses will come at a more mature time of life, at a time when man is confronted with realistic social problems, and consequently, at a time when such study is likely to be appreciated. The men enrolled will be taking the work of their own free will. Hence, inspired by a desire for further education, they will exhibit an earnest attitude. Complaints come from all directions that the engineer cannot write or express himself well. In this plan of study, it can be expected that written answers in the correspondence work will improve the engineer's mode of expression. Finally, we shall no longer need to apologize when we, as engineering teachers, are accused of producing nothing but narrow-minded specialists.

It should not be impossible for the engineering and arts schools to agree on the requirements for this kind of a B.A. degree provided we can once convince ourselves that it would not be a sacrilege to give an academic degree for correspondence work. If it seems impossible to agree to give a B.A. degree without designation, let us give, say, a B.A. in Engineering.

If the plan sounds difficult of accomplishment, keep in mind that something must be done soon about our system of turning out graduates into a complicated civilization—graduates who are unaware of the significance in this life of all the technical details with which we have perplexed their young heads. We should not forget that our function is to educate, and that education must not stop with a B.S. degree.

APPLICATION OF EDUCATIONAL PHILOSOPHY TO THE EDUCATIONAL PROCESS IN A PROFESSIONAL ENGINEERING COURSE *

By R. L. SWEIGERT

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I

Education is in a transitional stage from the philosophical to the scientific, and in the future will be much more scientific than at present. However, in being an applied science, it will never approach exactness, and since it involves the human element with all of the human variations, it may always have a large portion of its foundation built upon an educational philosophy and psychology.

All of our philosophy however is useless unless it is translated into actual activity. It is the writer's purpose to emphasize certain educational philosophical ideas, which it is believed, in the light of present experience, are ideal, and to show how these ideals have been applied directly to the educational process. It is only in such application that we may improve our educational technique, which in the mind of those connected with educational institutions, should rank in importance, side by side with professional development and research.

I believe that all of our educational philosophy should go back to one fundamental postulate. That is, that each individual has the inherent right to a full development commensurate with his ability and effort. When he has reached the utmost in development based upon his native endowments, then he should automatically pass out of the educational phase to active participation in the occupations, business, or the professions. Only one part of this postulate has a bearing here. That part implies as full a development as possible in relationship to ability and effort in each subject that the student takes.

Accepting this first fundamental, we necessarily follow to the second, that the individual is the center of instruction and not the group. Group instruction seems to be the most common arrangement.

The third point is that a development commensurate with ability and effort means not an acquiring of a large mass of information,

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but the growth of the individual's ability to travel along uncharted paths, based upon accurate fundamental concepts and upon the ability to perform the process which we call creative thinking. We speak about developing leadership. The development of leadership is producing growth in creative thinking.

A fourth concept develops from the fact that we all must have something to work for, incentives to produce the driving force necessary for accomplishment. These may include all grades of incentives from the highest type to that of the direct driving of the individual by the instructor.

A fifth point is the providing of a bridge, if possible, from the individual's past experience to the new, saving the jolt that may be caused by an abrupt change from the old to the new.

Having in mind these five fundamental educational principles, the development of the individual to the maximum commensurate with his ability and effort, individual instruction, creative thinking, incentive, and transition, the writer has attempted during the past two or three years to develop a technique of educational procedure in the classroom which would satisfy the fundamental concepts as set down.

II

The final method as given, was obtained by the writer through the coöperation of all the students involved. The results represent the composite thought of all concerned in the experimenting. The experimentation was carried on as outlined below.

Since our whole philosophy centered around the individual, attention was turned immediately to the individual.

No phase of standard technique, such as lecture, problem work, recitation, etc., seemed adequate as a basis for individual instruction, while at the same time teaching a regular class group. So other means were sought. There came to mind one principle of industrial management known as the exception principle, in which the executive who would otherwise be overwhelmed with detail, arranges a system with his subordinates whereby only exceptional and difficult problems need to come to his own attention. Thus, he can spend his time most profitably.

In checking over standard class procedure the conclusion was finally reached, based upon experience both as a student and teacher, that a large portion of the material covered in the classroom could just as well be covered by the student outside of the class time without any extra help other than reading assignments. Also, it is well known that what may be difficult for one student is easy for another, and there are relatively few items that are difficult for everyone. Thus the exception principle might be applied.

Therefore, to get individual instruction with a group in a limited time, it was felt that if some scheme could be worked out whereby each student could cover on his own initiative all material that gave no particular difficulty, the class time would be sufficient to discuss individual problems with the individual concerned, and when an item became a group difficulty it could be taken up in group discussion. This procedure seemed to call for some kind of a basic guide.

No textbook seemed adequate as the necessary tool to put the above arrangement into operation, as the usual textbook does not bring out effective emphasis and guidance of study as is certainly necessary where the standard class lecture is omitted. It was felt that a proper study guide, a special outline form, would solve this difficulty. Also, since the outline was to be used for a senior professional course, it was thought that it would considerably broaden the course if no specific book were used as the basis of the outline, but rather the fundamental technical material involved in the whole subject.

This guide was prepared with proper divisions of material. With each minor division was listed a series of references, the essential points involved, and a question sheet as a basis of self evaluation, and also, as a basis for objective type examinations, which form another branch of this program of educational improvement.

Being optimistic we thought the outline would solve all problems. Two classes were started out on these outlines. Both classes being made up of seniors in an elective course, it was felt that the stage was all set, so that all that had to be done was to turn the outlines over to the students with the necessary preliminary instructions. Then as the students studied the field as exemplified in the outline, they could check difficult points. These points were to be turned in. Each point was taken up with the individual or group who turned in that particular point. Meanwhile the others could proceed with their study with the outline as a guide. A large number of reference books were brought into the classroom for this purpose. The only assignment or schedule felt necessary was a schedule of tests. To allow for differences in speed at mastery, the test schedule was not absolute. The schedule was only a guide for a distribution of time over the semester. The tests could be taken by the student as soon as and when he felt that he was ready. Thus the better student could better adapt the course to himself, and had considerable leeway in expansion of the material to suit himself above certain essentials.

However, as anyone knows who has tried going from one method of practically complete supervision to one of nearly complete freedom, in one step, there are transition difficulties. A change from

daily page assignments, definite set tasks, and lectures, all through the course, in which in general if the student memorizes, he can get a high grade; in fact a change from a position where there has been little call for the student to exercise his own initiative, thinking, or responsibility, to a position of entire self-dependence, cannot be bridged in an instant, where the whole preceding educational scheme has been closely directed.

The sincere student, in fact, found himself quite lost for a period of a month or more. On a percentage basis of the total time involved that percentage was appreciable. All tools were there with which to work, but until the student learned how to use them he was in great difficulty.

Therefore, a satisfactory transition became necessary in both the method and the subject material. The transition in the latter was readily taken care of by the outline. The transition of method was taken care of by starting in the standard way, with the rate of shifting to the new method depending upon the particular class involved. This transition period may be anywhere from a week to a month.

If our educational scheme from the kindergarten to the exit from college were one of increasing self-determination, and decreasing outside control as it should be in fact, as well as in theory, the following point would be given no consideration. But as such a condition does not exist, it means that when a change is made from control to freedom as already mentioned, the creation and the maintenance of interest, achievement ratings, testing, and the desire for betterment on the part of the student may not even be sufficient to cause him continually to put forth his best efforts. The above statement applies to the average student, and not to the very best, who constitute a small percentage of the total.

The engineering student has many calls upon his time. Therefore, when the other courses are controlled and one or two allow freedom, it follows that those uncontrolled courses may suffer due to student procrastination.

Thus, in addition to the incentives already mentioned, there must be something of the older type of drive used which keeps the student moving at a certain minimum pace. Then as each student shows he has powers of self-locomotion, he may go ahead on his own initiative. While I am not sure that it is the proper thing to do, for those students who never seem to get up enough self-driving force, a force may, however, be kept at their backs so that they get a possible maximum education from the work covered.

Creative thinking is aided by the form of the outline itself, which not only raised much unprecedented discussion during

scheduled hours but led unexpectedly into a large amount of group discussion outside of scheduled time. The outline formed a basis and guide for discussion which I do not believe would have taken place without it. Not having a definite set of lectures to tie to, the student was forced to dig out many things. Using several different sources a wide range of viewpoints was obtained. Since viewpoints were opposed to each other in many cases, the student was more or less forced to analyze them to the best of his ability, and generally would arrive at fundamentally sound conclusions which was the only restriction placed upon his thinking.

At first, test questions were selected directly from the outline. This produced a great incentive to the use of the outline upon its first application. But this led, if you please, to undesirable memorizing on the part of some students. Therefore separate test questions of the new type examination were arranged. At the present time, there are some 4,000 items based upon the outline, arranged to be answered on the basis of thinking, not pure memory.

A continuous problem, in which each student works on a particular set of specifications, now runs throughout the term and creates thinking through the application of principles to a concrete situation that is not just a series of exercises. At the end of the term there is thus a series of comparable calculated situations which cause discussion and thought.

Those students who show a high standing the first month are allowed a substitution of creative papers for all following tests. As other writers have already mentioned, such papers are one of the best means of producing creative thinking. The creation of the paper itself is a thinking process.

Thus each individual, by *controlled freedom,* is given the opportunity of maximum development, generally and technically.

III

The first scheme with the outline and the use of the exception principle with no lectures resulted in the following data from the students' viewpoint. This check-up was made in internal combustion engines. It is realized that these opinions may be classed by some as coming from immature minds, incapable of forming judgments on the questions asked. However, the writer believes that the composite opinion tells a story. Written items turned in voluntarily plus also the large amount of discussion of the method by a large number of the students showed the fact that there was considerable thought back of the results obtained. Also, the fact

that most students are quite familiar with internal combustion engines before taking the course, makes the results still more valid and reliable. Also, it was emphasized that the student should check the doubtful column if there were any doubt in his mind concerning the results. The results follow.

TABULATED RESULTS

NUMBER OF STUDENTS—54

No.	Item	Yes	No	Doubtful
		In per cent		
1	Do you feel you have obtained a good fundamental knowledge of internal combustion engines?	66	7	27
2	Did you have any previous interest in internal combustion engines?	86	11	3
3	Did the course create any interest? (Might be in any special phase)	89	9	2
4	Was the course generally interesting?	80	7	13
*5	Do you feel that the time spent was worthwhile	87	0.0	13
6	Did you concentrate on answering questions without giving full thought to the questions as related to the subject? Did your object become the answering of questions instead of studying internal combustion engines?	21	55	24
7	Did you think the course too theoretical?	14	81	5
8	Did you think the course too practical (Tend too much towards nothing but mechanical details without sufficient underlying causes)?	8	86	6
9	Did the course seem to combine properly sufficient theory and practice so that the application of all theory to the practical engine and its effects upon the practical engine was clear?	48	31	21
10	Did you have trouble interpreting questions? Were there many chances for double meaning?	67	21	12
11	Do you feel that it gave a broader knowledge of the subject than you have received under the standard way?	61	12	27
*12	Did the use of the questions cause more discussion on the subject between students than would otherwise be the case outside of class time?	74	13	13
13	Did it cause confusion by having answers repeated by questions which brought out different points of view on various items?	19	56	25
14	Did it help your thinking? Did you consider the repetition as helpful in getting a wider and more complete view and knowledge of various items?	68	16	16

TABULATED RESULTS—(*Continued*)

No.	Item	Yes	No	Doubtful
		In per cent		
15	Would a regular schedule of lectures of from 15 to 60 minutes, depending upon the subject, tie the material together and thereby help the student get a better grasp of the subject?	84	4	12
16	Would you recommend a certain number of questions be assigned each time as the basis of above lectures?	68	16	16
17	Would the use of a note book in which complete notes of reading would be recorded and which would be checked once a month help you in getting the work?	60	25	15
18	Did you tend to let studying slide as long as possible, and cram for quizzes?	52	31	17
*19	Do you tend to do more thinking and get ideas of your own on the subject under this system?	61	22	17
20	Do you feel that the class period itself is more interesting and less dry and boresome?	78	9	13
21	Do you find the ideas better fixed in your own mind by this method?	64	12	24
*22	Do you feel that this system makes the course more flexible to meet your own interests better?	75	9	16
23	Did you find that this system took more or less time than the standard course? Same	27	52	21
		more	less	
24	Would you consider the selection of a minimum number of fundamental items on each unit plus a certain number above the fundamental items, the added number to be distributed as the student likes on whatever division he chooses?	52	15	23
*25	After finishing the course did you have any desire to do any further specialized study in this field?	66	20	14
*26	Do the notes give you a definite method of study? (A useful guide in studying.)	84	8	8
*27	Do you consider this system has offered you advantages over the standard way so that you feel that its development is worthwhile from the student's viewpoint?	73	11	16

As an over-all view and summary, check the following which are considered as the aims of the course:

		Yes	No	Doubtful
*1	To give a good technical knowledge and foundation, both general and for those who would like further advanced study	82	2	16
*2	To make you think for yourself (original thinking). Not to turn out a lot of predigested stuff	72	14	14
*3	To make it as interesting as possible for all students	84	0.0	16

The tabulated results need little explanation. However, general attention may be directed to items 1 to 5, 12 to 14, 19 to 23, and 25 to 27, with particular attention to the starred items 5, 12, 19, 22, 25, 26, 27, and the three aims at the end of the table. The writer would personally pick item 25 as one of the best indicators of the success of the method.

Items 10, 15 to 18, and 24 form a definite basis for further improvement. In referring to item 15 it may seem like turning back to an approximation of the lecture system, but such is not the case. It was much emphasized that lectures should be short, generally not more than 30 minutes, and should be given only at the start of each new division.

IV

Representative student comments follow:

1..... The course seems O.K. to me. The trouble lies in myself. I have a tendency to let things slide to the last minute. I think the course is of special benefit to me as it is getting me out of this habit.

2..... I would endorse this method without reservation provided my work consisted of one or two courses on which I could spend as much time as necessary. As it is, our time is limited and adding to that difficulty in obtaining information due to the restricted periods of time in which sources are available, there results a tendency to procrastinate. My personal opinion is that a compromise of the lecture and this method would be more suitable under the circumstances.

3..... Assignments are too widely distributed. Aside from the above I prefer this method of study to any other that I have used.

4..... The method of giving the course is very good indeed I think. However, it takes a great deal of time to do the reading. The lecture given last Friday was a big help for my preparation of the work. Lectures such as that will help to solve the difficulty above.

5..... The chief difficulty has been lack of reference material, but this should soon be obviated due to broadening of the field. I am heartily in favor of the grading system.

6..... This method is good because more ground is covered which is along lines of special interest. More responsibility is put upon the student and for this reason some friction will result, due to the radical differences from usual courses.

7..... I find difficulty in securing adequate time for study. I like the opportunity for individual study and chance to follow the particular phases of the course that are of individual interest. I suggest that we have more time allotted for more general discussions along with a directed short lecture.

8..... I am getting more out of the course by using various references than if I were studying just one text.

9..... It requires a great amount of time. I find that due to lack of class discussion, the relative value and mental impressions that should be affected are sadly lacking. My suggestion is that we all do general reading of the text, but that we be assigned individually to make a specialized reading on a particular subject and deliver in class time our résumé of our study and the critical points. The individualized specialized research could thus go so far as to dig up information in the current periodicals and catalogues.

10..... It has brought me to realize fully that one can learn if he puts forth the effort.

11..... The class period is better this way, because we know what we need to get, whereas a professor may lecture on something we have already read and understood, therefore making a waste of time.

12..... More points should be covered in class so that we will not draw wrong conclusions.

13..... The course was very satisfactory and enjoyable.

14..... It would be impossible to select a textbook that would cover as much theory and practice in the same length of time as we covered by the method used. By taking daily assignments from a textbook, points would be covered that were not needed and some important items omitted.

15..... With a few exceptions, I think students at Georgia Tech, as elsewhere, need to be forced to study. No matter how much interested one may be in a subject, he will not put time on it if his other work is heavy enough to keep him busy all the time. The supposition that seniors are old enough to know if they want to study is in error in that they have so much work that they are likely to neglect the subject that will show that neglect the least.

16..... We did not feel we were driven to work and therefore became more interested and got more out of it.

17..... The questions most decidedly caused more discussion.

18..... This was one class that gave no one an excuse for going to sleep. It was generally understood that an informal discussion is the best way to understand difficult points. In fact, many modern institutions are introducing this method and possibly the M. E. 166 course will be the leader at Tech.

19..... At the beginning of the course I was more or less dissatisfied with the course. As the time went on, four of us grouped together and would divide the questions of a division and assign one group to each one. Then a time was agreed upon for each to have his questions answered. Then we would meet and each would explain his group of questions and invite criticism. In this way several opinions were introduced and personally I think that we derived better results from this method than we would have from the regular method.

20..... There are some advantages in this system in that the student gets a much broader knowledge of the subject by studying the viewpoints of more than one man.

21..... From the standpoint of originality, definiteness of purpose, and flexibility, I think this method is good.

22..... The student feels as though he has more freedom and is able to express some ideas of his own. The class seems more interesting and there is no desire to sleep.

23..... Classes conducted in this manner give more room for discussion of practical problems and this is more interesting. Interested students get more out of the course.

24..... The greatest advantage as I see it, is that this method gives a person a chance to study along the lines he likes best. It leaves out a lot of unnecessary items that a book might stress. About the only disadvantage that I see is that a large number of books must be consulted in order to obtain the information, thus perhaps taking a little more time.

25..... Using this method of teaching makes the student think more than it would to assign something definite in a textbook.

V

There is so much flexibility to the arrangement to meet the varying needs of classes that it is somewhat difficult to give exact detail of the method. However on the basis of the philosophy already stated, in conjunction with the tabulated results, educational psychology, and our best judgment, the procedure finally evolved is somewhat as follows.

The outline and its arrangement and content are the backbone of the method. Definite weekly assignments are made for the term, these assignments being based upon the outline. A definite test schedule is given for the term which is now inflexible, except for legitimate excuses, such as sickness. The main calculation problem is given a definite schedule which is to be met also. The above three items form the force to mitigate procrastination. A certain definite minimum is required of all students in every division. A definite number of added assignments are left to the student's choice. He must select a certain number of items for special investigation, but the selection is his own.

With the above tools the high grade student is capable of going ahead on his own responsibility. As far as that type of student is concerned, the above, plus individual conferences, which are quite often outside of class time, constitute the arrangement. Thus with this type of student no scheduled class time is necessary.

But for many students this arrangement would not be satisfactory. Also, our school regulations make class attendance compulsory, except for honor students. Therefore, additional arrangements are made. Also arrangement must be made for a transition. The first week of the term is conducted along standard lines, using the outline similar to a textbook. The second week is modified to suit the class. The responsibility is put upon the student as fast as it is apparent that he will carry it. After about the third week, the weekly schedule for a three hour course will be somewhat as follows. The first hour comprises an informal discussion on the week's assignment, covering the salient points. The instructor, if the group requires it, takes a dominant lead in this first discussion in order to concentrate attention at the more important points. If the group is poor this discussion may carry over to the second hour. If the group is very good, it may be ended in 15 or 30 minutes. The subject matter also affects the length of this preliminary discussion.

During the second hour, after all items of individual and group difficulty from outside study have been taken up with those concerned, a discussion of special assignments to individuals is taken up. This may be individual or group as the particular situation demands. The third hour is started by first taking care of indi-

vidual difficulties. This is followed by the individuals who have investigated special phases, giving the benefit of their work to the others. Sometimes there may be more than one group in the class, and sometimes only one group, depending upon the interest in, and the importance of the particular phase concerned. While weekly assignments are made, it does not imply that they are all on different subjects. If more time is devoted to a particular part of the field, the rest of the days following the third are similar to the third day, until the subject is covered.

It is made known at the start of the course that those who are above a certain rating at the end of the first month will be free from further written tests, if they choose to be, by substitution of papers of a high order.

A progress check of these students is made through the individual conferences, and oral questioning. If it happens that the necessary progress is not being made and the papers are not of a high order, the student is required to take the tests. He has complete freedom as long as he progresses. His freedom diminishes as his progress on his own responsibility diminishes.

It should be mentioned that no individual is obligated to listen to any discussion. While a discussion is going on, either general or with an individual, a student may, if he so chooses, continue with the outline with the aid of reference books. He may sign in at the library where a large number of books are placed on a book stack close by a table especially for use in this work. Sometimes a student may spend the whole class hour in the library. If a general discussion is scheduled he may participate in that discussion as long as it meets his needs and then retire for reference work, either in the library or adjacent to the classroom.

VI

Certain results became evident with the operation of the above arrangement.

1. The greatest difficulties were student procrastination and time lost in getting started at the beginning of the course, both of which difficulties, it is hoped, have been overcome.
2. The average undergraduate student is not capable of carrying a course entirely on his own responsibility.
*3. Individual instruction could be made to work with a group of 15 to 20 students.
4. There must be exact assignments made for relatively short intervals of time and a check on those assignments is necessary.
5. Special assignments are much more effective when the initiative for that assignment comes from the student.
*6. The use of the library by the student was tremendously increased.
7. The use of reference books was increased.

8. Group discussion outside of class periods was greatly stimulated.
*9. The class became a genuine coöperative affair with the instructor as a guide.
*10. Interest was stimulated.
11. Students set up problems on their own initiative, trying to solve problems for which they found no solution, which along with other items caused creative thinking.
12. Course objectives were apparent to the student.
*13. Individual responsibility was developed.
14. The student felt that he was an important part of the group and that he had an opportunity to develop according to his own capabilities.
15. A definite method of study was set up.
16. A greater amount of ground could be covered effectively than under the old way.
17. This method required more time on the part of most students (More time was spent in study).
18. It formed a good transition to graduate work.
*19. Class time could be used to the best advantage.
*20. After certain changes were made, it met our fundamental principles.

This method may be applied to other fields than the one in which it was tried. The writer is working on its application to thermodynamics. It is being adapted in a different manner, however, so that difficulties that were encountered in its adaption to internal combusion engines will not be met. Also, certain modifications may be necessary due to the subject field itself, as reference work will not be necessary in the same manner and degree as in the engine field.

It is hoped that this paper has put the necessary emphasis upon the student, because the writer feels that as instructors become more and more engrossed in their special fields, subject matter becomes so dominant that the student as an individual is forgotten. The best work can be done only when the student is considered just as important as subject matter.

HISTORICAL ASPECTS OF MINING AND METALLURGICAL ENGINEERING*

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Throughout the long sweep of history men have been using minerals to maintain and improve the conditions of their existence. The word mineral is here used in its broad sense of including everything that is neither animal nor vegetable, not in its narrow sense as defined by the mineralogist. For, among the substances most useful to man in improving the conditions of his existence are the metals, which he typically produces from natural minerals by the exercise of his slowly acquired metallurgic knowledge and skill. Since the acquisition of knowledge, though a pre-requisite to engineering, is not engineering, and since the exercise of skill bears only a similar collateral relationship, this review will not be limited to the bare bones of the history of mining and metallurgical engineering, which have only the same relation to the whole subject that a skeleton does to the human body.

Any one of the various bases of division might be employed in sub-dividing history. It seems wisest in the present instance to choose for the first epoch all time prior to the sixteenth century, because the discovery of the New World resulted in a great stimulus to interest in mining and metallurgy, and it also nearly coincides with what may be called the beginning of the literate period of mining and metallurgical engineering. The second is the time between the end of the fifteenth century and the middle of the nineteenth century, which will include the discovery of the human value of coal, and the development of the ability to make iron in quantities sufficient for the new uses that had been discovered for it, which in turn were an effect of the discovery of how effectively to control and utilize the carbon content of iron. The third epoch, from the middle of the nineteenth century to the present, is not only a period in which the total quantity of minerals produced and used is at least double that of all previous history and petroleum begins to be an important factor in human life, but also shows a tremendous advance, through a deeper and more precise knowledge

* Three lectures delivered at the Mining and Metallurgical Session of the Society's Summer School for Engineering Teachers, University of Wisconsin, July 6, 7, 8, 1933.

of the physical properties and of the constitution of alloys, in our ability to utilize minerals and metals to serve new and important purposes.

The First Period

Although I have given a date for the end of the first historical period, there is not even an approximate date for its beginning, since neither the paleontologists nor the archaeologists know exactly how far back that reasoning anthropoid, man, can be traced. The skeletons of some 10 individuals found near Peking are thought to be about 500,000 years old. They are designated as Sinanthropus,* and like the skull from Java, called Pithecanthropus (thought to be about 400,000 years old), are not true men but related genera. Whether they used minerals we do not know, for the only record we have of them is a few bones. The Neanderthal man is supposed to date back about 50,000 years. For our purposes about 20,000 years is the practical limit of the first period, since that takes us back to the Cro-Magnons of Europe, with their three sub-divisions of Aurignacians, Solutrians, and Magdalenians, who represent a culture advanced enough to make important use of minerals to serve human purposes and, because they buried their dead in caves, have left enough remains to reveal something of how they lived.

One point regarding this dawn of mineral history that must be emphasized is that there were some things which workers early learned to do that cannot be improved upon. When David played upon the harp for King Saul, 3,000 years ago, he probably played it as well as anyone could to-day. The gold vase, made in 2900 B.C., a picture of which is used as a frontispiece in Breasted's Ancient Times (which is about the one best book to read on early history) is, in beauty of design and skill of execution, as good or better than the gold salt cellar that Benevenuto Cellini made for Francis I 4,500 years later, which is kept in a museum as an example of fine metal work of the sixteenth century. The principle also works both ways, and a Boy Scout leader has stated that in a couple of afternoons he can so effectively train boys in the procedure used in chipping flint to make arrowheads and cutting tools that those who have any natural aptitude for handwork can turn out work equal to the best done by the ancients.

The second point, and it cannot be overemphasized, is that when early man learned how to do things, he typically did not know why he obtained the result he did. He did not need to know why; the important thing to him was to get the result, not to explain it.

* Since these lectures were given much evidence has been presented to support the view that Sinanthropus was a true man and lived at a much later date than was first assigned to him.

Only in the last couple of centuries has it been important to the artisan to understand the how and why of his procedure. That, of course, is because of the quickening of the tempo of technologic advance. We now improve a process as much in a year as primitive man did in ten centuries.

There is a corollary to that point, namely, to be on our guard against imputing to ancient man an understanding of his technique that is perfectly obvious to us, but was a sealed book to him. A good example of what I mean occurs on page 42 of Brose's translation of Neuberger's "Technical Arts and Sciences of the Ancients" where, after describing an ancient bronze die containing 75 per cent copper and 25 per cent tin and noting that it was well suited to the purpose for which it was intended, he goes on to say: "The fact that this alloy was chosen as having all those properties simultaneously and that it contains no trace of any foreign metal that might have affected those properties shows how clearly the influence of chemical composition on physical properties was recognized even at that time." Of course it shows nothing of the sort any more than the steel made in 1400 B.C., by the Hittites indicates that they understood the carbon-iron diagram, which actually was not to dawn on human consciousness until some three thousand years later.

If we understand aright the period of the Alchemists, near the close of this first period, we will recognize that at no time in the whole period did men have any clear understanding of the effect of chemical composition on physical properties because they did not have any clear understanding of chemical composition. Their efforts to produce gold from other metals, that seem so silly to us now, were perfectly logical from their viewpoint. They knew they could take copper and by melting it with tin produce a metal that was so different in color and physical properties as to rate as a different metal. They could treat iron so that it changed from being soft and ductile to hard and brittle. And by heating copper in powdered calamine they could change it into brass, again a change of color and properties that made it seem a different metal. They knew how to do those things, but they did not understand how or why the result was produced.

To understand the long struggle to acquire metallurgical knowledge one must understand the nature of the learning process, as modern psychologists view it. They divide it into a recognition of the problem and the development of means to meet it. Sometimes one and sometimes the other is the "neck of the bottle." For example, in piano-playing anybody can at once recognize that the problem is to hit the keys in proper sequence, but the doing of it is only learned by long and patient practice; some people can

never learn it at all. A baby in a crib who tries vainly with arms and legs to reach a toy outside, and finally hits on raking it in with a stick that is lying inside, is an example of something that is easy to do once you really grasp the problem. As soon as primitive man hit on the idea of chipping a flint to give it a cutting edge he could do it as well as anybody can. Metal workers could work gold thousands of years ago as well as they can to-day, but the early metallurgists did not understand the effects of carbon on iron and consequently only acquired an imperfect control over the carbon content of iron with great difficulty.

The great problem of early man therefore was to get an idea of useful things to do; if he could understand his problem he could generally learn some way to solve it. One of his greatest early steps was to notice that fire had an effect on clay; after burning it was different. This did not strike him as strange, since the fire completely destroyed the fuel, but it was only slowly that he came to see how he could utilize this effect. That was the real beginning of metallurgical science. But let us guard against attaching too much importance to the physical fact. As Charles F. Kettering has said, a "problem is not solved with apparatus, it is solved in a man's head." It was the noticing of what happened, and the imagination to think how it could be usefully employed that was important.

Once he got the idea of burning brick, man was able to make them about as well as we can now. All that thousands of years have added is a knowledge of how original composition of the clay affects their service, and a reduction in the labor of making them through the application of machinery. The Babylonians not only used them to improve building construction, but also as an easy way of making imperishable records in a world that till then had been limited to laboriously carving inscriptions in stone. A clay tile has its obvious limitations from a librarian's viewpoint, but it is a gorgeous thing from the viewpoint of the archaeologist.

The first definite date we have in history is 4241 B.C., when the Egyptians invented a calendar. We have little in the way of records before 3500 B.C., for a few inscriptions are older than that. Before 4241 B.C. time periods have to be estimated as we do in geology. The relative times of the development of culture in Egypt, Crete, the valley of the Tigris and Euphrates, Asia Minor, and the Northern Mediterranean can be found in ANCIENT TIMES.

Many of you probably do not know that the alphabet seems to owe its origin indirectly to mining. The accepted view is that the Egyptians in carrying on copper mining operations on the Sinai peninsula from perhaps as early as 5000 B.C. on, and especially after 1850 B.C., used native workmen supervised by Egyptian foremen.

The foremen, as usual, found it easier to learn the language of the natives than to teach them Egyptian. That was satisfactory for speech, but while the Egyptians could write in their own language the natives could not write in theirs. Some unknown genius, about 1850–1800 B.C., hit on using modified Egyptian characters to signify a sound instead of an idea and thus, through combining them, made it possible to reproduce the sound of an alien word. Such was the beginning of alphabetic writing, and it is interesting that one of these earliest inscriptions, found in a mine shaft, reads, "I am the miner Sahmilat, foreman of Mine No. 4." So we of the mining profession can claim an important connection with the world of letters from the very beginning.

One of the traditions of archaeology is to divide the history of human culture into stone, bronze, and iron ages. This is not to be confused with poetic allegory, such as that of Hesiod who, writing in 800 B.C., placed the golden age of man in the then remote past, though we know very well that five times as much gold has been produced in the past hundred years as was produced in all preceding human history. The archaeologists mean that the minerals used were first (before 3000 B.C.) predominantly stone (I would prefer to say non-metallic, so as to give its due place to clay); then bronze (3000 to 1000 B.C.); and finally iron (after 1000 B.C.). There is general agreement as to the first period and disagreement as to the second and third, chiefly arising because no clear distinction has been made between copper and bronze, also the doubt that arises about the early use of iron (through the possibility that the earliest specimens may have been lost through corrosion), and because men acquired their knowledge at different times at different places.

There can be no doubt that the first metal used for practical purposes by men was copper; not only because it occurs quite commonly in the metallic state but because we have actual evidence of its use. You can see in the Oriental Museum at Chicago not only stone vases of which the interiors were cut out by rotating a copper cylinder fed with sand or emery, but the cylinders and the cores that were removed as well. This goes back long before the use of either iron or bronze in Egypt. There seems to be a good deal of evidence that men knew how to make iron before they worked extensively, at least, in bronze and the relative importance of the two seems to depend on whether tin ore was easily available and how fast the metallurgists progressed in learning how to handle iron.

Metallurgists will at once recognize that while the early metal worker had no difficulty in working metallic copper he got into trouble as soon as he tried to cast it because of the difficulty of

ridding it of the embrittling and blow-hole-making oxygen. It is still troublesome. Working in his empirical way he must have tried adding all sorts of things to see if they would do any good, and was lucky enough to find that some of them did, producing a sound casting of darker and harder metal that could be given a hard edge by hammering it. He did not understand the relation between chemical composition and physical properties, as Neuberger imagined; he simply knew that if he did it that way he got good metal. And he did not produce the metals separately and then melt them together as we now do; he smelted mixed ores. The evidence on that point is quite clear, since the Chinese made copper-nickel alloys more than a thousand years ago and do not yet produce nickel metal.

Our difficulty in understanding the early history of bronze is mainly an intellectual one, since, although we to-day use the word bronze to mean a metal that may contain lead, zinc, nickel, antimony, and even aluminum, iron and manganese, as well as copper and tin, we have a mental picture of it as consisting of four fifths copper and one fifth tin. Then by another mental jump we think of taking four pounds of copper and one of tin and melting them together. Of course nothing of the sort happened in early times. Primitive man first picked up pieces of copper that were large enough to be useful and worked them up into the needed shapes. When he had learned from observation to use a bellows to intensify his fire he was able to melt small pieces so as to get a larger piece. Sometime after that he noticed that the green material he found along with the copper would yield metal in a hot fire, and thus greatly increased his supply of raw material. Fortunately for him he could never collect a supply of oxidized copper ores that were entirely free from sulphides, thus helping in his deoxidation. When he found that by roasting sulphides he could reduce them into copper we shall probably never know, but we can be sure it was only a result of long experience and observation. As soon as he got beyond the metal-melting stage into smelting he was always working with mixtures of minerals; he hand sorted them and used those that he had found by experience gave him good results.

To recapitulate, man began his use of metals by picking up pieces of native metal, usually copper or gold. He soon learned to work them with great skill. Later he learned to melt small pieces and form a cake large enough to work. Much later, probably as a result of metal melting, he learned how to produce metal from ore by fire treatment. The three stages of progress are metal working, metal melting, and metal smelting.

Somewhere along the line he found that by heating iron ore he

could make a metal from it. So long as he was content to make a bloom of nearly pure iron, to be worked into shape without melting, he did not need a high temperature or much equipment. He could not melt it; it was softer than copper and did not seem to be of much use except for wire and a few other uses where a soft metal serves. When he found that by heating and hammering he could weld it, that was an important discovery, for it greatly lessened the work of fabrication. I take no stock in most of what has been written about the early use of meteoric iron, and its serving as a guide to the production of iron from ore. I do not believe early metallurgists recognized any connection between the two, for the properties of most meteoric iron are such that he would not think of it and the soft iron he made as being the same thing at all. Besides, all the evidence indicates that meteoric iron was regarded with superstitious awe, and was usually put in the early equivalent of a museum, just as we do now.

But the great achievement of this early period was learning that if soft iron is packed in carbon and heated it becomes hard. Whether this was a chance discovery or the result of careful observation, it is useless to speculate. But we have abundant evidence that as early as 1450 B.C. the Hittites were making nearly carbon-free iron that they worked into shape by forging and then hardened by what we now term cementation. The early metallurgist knew nothing about the effect of carbon on the properties of iron, he just knew how to do it.

There is no truth in the popular myth that the ancients could do better work than we can do to-day. Of course they could do nothing of the sort. They made a great deal of material and some of it was good. The good was highly prized, carefully treasured, and the unthinking now refer to it as typical ancient work. Actually it was rare and exceptional ancient work, turned out at high cost in human effort. A sword was forged out of soft iron (which was pure if the ore was carefully selected), and then converted into steel by cementation with carbon. As I said of playing the harp, there was no reason why the early worker could not do it as well as it can be done now. Both the ancient and the modern worker do it as well as that particular job can be done. There are no lost metallurgical secrets of the ancients.

In the reduction of iron oxide to iron by heating it with carbon the early worker undoubtedly got some pieces that were high enough in carbon to be hard and brittle. He tried to avoid this, for they were no use to him. It is curious that he did not sooner discover that he could melt and cast them as he did bronze. (Casting in molds was developed very early and a good review of its history, by B. W. Johnston, can be found in the PRO-

CEEDINGS of the British Foundrymen's Association, 1915–16). The Chinese seem to have been the first to discover it, and the earliest castiron objects known, dated from about 200 B.C., can be seen in a case in the Field Museum in Chicago. The art developed rapidly in China and the Chinese were making castiron statues more than life size at least 500 years before the first cannon balls were cast in Europe. The probable Chinese method of iron production is illustrated in my paper in the 1912 volume of the TRANSACTIONS of the A. I. M. E. The method used in the West to reduce iron produced less carbon absorption and it was not until the larger furnaces of the Middle Ages grew big enough and hot enough that melted iron began to be produced there. It made its way slowly and not much cast iron was used in Europe until the development of machinery.

I wish I could tell you when men found that from the hard, brittle melted iron they produced in their furnaces they could make soft iron, but I do not know. It seems to have originated in Europe a little before Renaissance times. Agricola in his DE RE METALLICA seems to be describing such an operation, and a better account of it can be found in Biringuccio's PIROTECHNIA. The chapter on iron in human industry in T. A. Rickard's MAN AND METAL contains a number of serious errors, such as on page 884 where he speaks of the iron ore of Styria and Spain containing enough manganese "to change the iron into a mild steel," and on another page confuses the development of the iron blast furnace with the development of iron casting. The two are really independent, as it has already been indicated, and the Chinese made large castings without using a blast furnace.

My own guess is that in many places iron was made before bronze, as we definitely know it was in Egypt. Although there is a good deal in Chinese records about early bronzes, and Hsieh Shang-kung in the thirteenth century wrote a book on the inscriptions on ancient bronzes, we have very little on iron objects. Probably iron was abundant and cheap enough after 200 B.C., so it was only used for common things, while the scarcer and more expensive bronze was used for more valuable things, employed in connection with religious ceremonies and for palace decoration, which were not only more carefully preserved, but were commonly inscribed, so that the dates are known with much accuracy. Bronze in China goes back to the eighteenth century B.C., or a couple of hundred years before the earliest bronze in Egypt, the point being that the Chinese had access to a tin ore supply and the Egyptians did not until comparatively late in their history. Iron came into common use in Egypt about 1000 B.C., or about 500 years before it was equally common in China. The Incas, who

had an abundant supply of copper and tin, did good work in bronze, but never learned to produce iron by 1500 A.D.

Hence it follows that the division of time into Stone, Bronze and Iron ages is an arbitrary, rough, and somewhat misleading one. But in a crude way it conveys the picture that not much metal (except native gold and copper), was used before 3000 B.C., and not much iron was used before 1000 B.C. It is good enough for the historian, but not satisfactory to the metallurgist.

Enough has been said to lead up to my next two points. Two erroneous ideas are widely held: (1) that men discovered how to do things in one place and the knowledge was from there disseminated throughout the world, consequently (2) the sequence of metallurgical development was everywhere the same. The second is obviously not true. The Egyptians worked in copper for a thousand years or more before they learned to make bronze, while there is evidence that bronze in China goes back almost to the beginning of copper smelting. The obvious reason is that the Chinese had mixed ores to work with, while the copper ore in Sinai was free of other metals, and it was not till the Egyptians began to get tin from a distance that they made bronze.

As to the first point, that can be as easily controverted. There is no indication whatever that the Incas learned from anybody how to do their metal work, and the paper already cited pictures Chinese working in the twentieth century by methods that show no trace of two thousand years of progress in Europe, although there are abundant records of contact between the two regions throughout that two thousand years. Within sight of the great modern Tata steel plant in India, native metallurgists can still be found fabricating steel by the methods their ancestors used a thousand years ago. There are many other regions besides South America where we find metal work going on without any evidence of contact with more advanced people and *per contra,* there are many regions where the natives had contact with more advanced people but never learned any metallurgy from them. The story of advance in mining and metallurgy seems rather to be simply an important part of the story of the advance of general civilization. Some people had abundant raw materials available to them, like our American Indians, but never learned to make any important use of them, while others with a much scantier supply of minerals accomplished much with them.

Silver and lead are two metals on which the early evidence is more scanty, but such as we have confirms our natural inference that lead was produced very early, since it is so easy to reduce it from the mixture of oxidized and sulphide ores that normally caps lead deposits. It was probably not of much use in very early times,

but eventually more useful alloys were made. Lead was fairly common in Egypt by 1500 B.C. The hanging gardens of Babylon had lead pans underneath them and the Romans made extensive use of lead for plumbing and other purposes. There is a good deal of evidence that the main object of lead smelting was to obtain silver. There is much confusion about this, for the earliest evidence yet available of cupellation only goes back to 500 B.C., when it was extensively used at Laurion, in Greece. Hoover says in his historical note on lead and silver smelting (DE RE METALLICA, page 391) that he thinks the Chinese knew silver long before they knew lead because silver is mentioned in the Shu King in connection with a date as early as 2500 B.C., while we do not meet lead till much later. But there is some evidence that the Chinese smelted silver-bearing lead ores, cupelled the lead, and simply put the litharge on the dump, and there is so little in their literature on metallurgical processes that they may well have been cupelling long before any reference was made to it. Pliny obviously did not know of native silver, which shows how dependent on smelting they were for it at that time.

The parting of gold and silver is another disputed point, and some of the evidence people have relied on does not support their contentions. One writer says positively that Archimedes' discovery of the principle of specific gravity, to solve the problem of how much silver the maker had put in Hero's gold crown, proves that the Greeks did not know how to separate gold and silver. It does nothing of the sort, for an obvious condition of the problem was not to deface the crown. Nevertheless we know that the Greeks and Romans did not have mineral acids, so it could not have been done by inquartation. The historical note on page 458 of DE RE METALLICA will give the rather confused evidence as to how it was done about the beginning of the Christian era and the later developments need not detain us here beyond that when men began to work with strong acids in the early Middle Ages they could do many things they could not do before.

Quicksilver is a rather late metal, and we do not find much about it before Roman times, though I think if an adequate search were made of Chinese literature, we would come upon it earlier, for the Chinese have always esteemed vermilion as the most valuable of pigments. It is interesting to note that except for the patio process and detonators the workers in the Middle Ages made about as much use of quicksilver as we do, and, consequently, it was then relatively more important than it is now.

Next we come to the controversial subject of zinc, to which I happen to have devoted much study, so I must guard against discussing it at too great length. It is the subject on which Rickard

goes farthest astray, through neglecting to consider the records of China and India, where it obviously was first made. The point is, to use a Hibernianism, that zinc was not made at first, only used. Brass was in common use from the beginning of the Christian era, but it was all made by "cementing" copper with calamine until the beginning of the nineteenth century. There is no ground whatever for Rickard's assertion that brass could not be made until after zinc was produced as a separate metal, for we know very well that it was not made from metallic zinc for centuries after zinc metal was known. But just when was zinc metal first known? That is the question.

In special Publication No. 1 of the Indian Association for the Cultivation of Science, Neogi (Copper in Ancient India, p. 41, 1918) presents some evidence that zinc was produced as a separate metal in India as early as the seventh century. Briefly, he quotes from twelfth and thirteenth century Sanskrit encyclopedias a description which seems to be the retorting of zinc from calamine. With this as a guide a statement which appears in a seventh century encyclopedia is also interpreted to refer to the distilling of zinc. In the Bulletin of the Geological Survey of China, Vol. 2, No. 1, H. T. Chang reviews "the Beginning of the Using of Zinc in China." He gives analyses of Chinese coins, which, up to 1094 A.D., only contain one or two per cent of zinc. But coins of the reign of Chao-sheng (1094–7 A.D.) have the following composition: copper, 55.5 per cent; Pb, 25.8 per cent; Zn, 13.15 per cent; Sn, 3 per cent; and Fe, 1.5 per cent. A book on the monetary system of that dynasty says that the coins were made of four parts of copper, two of lead and one of zinc, which not only checks with the analysis but indicates that the metals were produced separately and melted together, since the Chinese did not have analytical methods, and therefore could only have known the proportion of the metals in the alloy by the proportions used in making it. It seems probable, therefore, that zinc was being produced in both India and China at least 600 years before it was known in Europe. Since people in those early days had no clear understanding of the difference between an alloy and a metal element we would not expect them to recognize zinc as an element.

The first commercial zinc in Europe was brought there from India by Dutch merchants in the seventeenth century and in 1721 Henckel published a paper showing that it could be distilled from calamine. Dr. Isaac Watson went out to China, saw the method of producing zinc there, and shortly after (about 1840) John Champion began producing it by the same method in England. A distillation method that was developed in Carinthia in 1799 was short-lived, but in 1805 Abbé Donay put retort distillation in Bel-

gium on a working basis. Production in the United States did not begin for fifty years more. Although zinc metal had been available in Europe for some two centuries at least, all brass was made there by cementing copper with calamine until 1781. The first brass made in America by melting zinc and copper together was in 1802. This story has taken us far beyond the end of our first period, but it illustrates the difficulty of coming to absolutely certain conclusions on the history of metallurgical development, and it also seemed wisest to finish the subject of zinc once we had started on it.

Too little work on a metallurgical subject may lead one astray. As an example, the historical note on silver and lead in the DE RE METALLICA (page 390) says that silver in China is mentioned in the Shu Ching, with the date 2500 B.C. added, but that lead is not mentioned until later. The Shu Ching is an historical treatise, now dated around the third or fifth century B.C., covering a period beginning with the twenty-fourth century B.C. and continuing down to 721 B.C. The earliest date actually mentioned for silver is 2200 B.C., and is only a mention of it as tribute metal. Of the Yin dynasty (1766–1122 B.C.) it says silver "overflowed from the hills."

It is not until 96 B.C. that we have much on silver in China. A biographer of Lü-Tsu, an alchemist who lived 750–800 A.D., says of him. ". . . among the five metals (gold, silver, iron, lead and tin) he made most use of lead, because from that he obtained silver." In the Ts'an T'ung Ch'i,* written by Wei Po-Yang about 142 A.D. (the earliest treatise on alchemy in China extant), the statement is made (ch. LXVIII) that "fire is white and produces yellow sprout (huang-ya) from the lead," which certainly sounds as though he were familiar with cupellation. In the Wu Chen Pien, written in 1075, it says: "In the gold furnace you must separate the mercury from the cinnabar, and in the gemmy bath you must precipitate the silver from the water."

This sounds as though the Chinese first prepared silver by cupelling and later precipitated it in the wet way. In a book of the Sung dynasty (960–1278 A.D.) it is said that Hsü-Yen used all the lead from the southern mints to make red paint, obviously by converting litharge into red lead. But we must be on our guard against placing too much reliance in these old records. Not only are they like our own Bible, where we read an account of Solomon's temple (960 B.C.), presumably derived from temple records made a century or two after the event, whereas the English translation we read is based on manuscripts written a thousand years later. But there are two other difficulties. Old Chinese characters differ as much from the modern as Anglo-Saxon differs from English, so

* An English translation can be found in *Isis*, Oct., 1932, p. 210–289.

the students of the ancient records are in doubt in identifying the old characters. When they decide that two old characters are the equivalent of modern ones that mean "white tin" they still have the problem of guessing what it was that the Chinese called "white tin" at that time. The result is sometimes a flat disagreement between authorities and much uncertainty at the best. This difficulty is common to all the old records in any language.

The reader of this review will wonder why the discussion of mining has been postponed so long. The reason is that there is so little we really know about it. Obviously the first mining was simply the digging of pits, but where the mineral sought occurred in stringers it would be clear that labor could be saved by following it underground rather than making a big pit. How early this was done there is no means of knowing, but we are sure it was at least as early as 1850 B.C., because we know an inscription of that date which is within a shaft. It goes back thousands of years before that, surely, for archeologists have found in Europe the remains of underground workings for flint that, while not very extensive, show the general principles of shaft-sinking and underground excavation. There was a sudden increase in tin production around the Mediterranean about 1500 B.C., and while we know almost nothing about it, it is probable that tin was mined underground very early, for it characteristically occurs in veins. Underground mining at Laurion, in Greece, was extensive about 500 B.C. and perhaps began much earlier, for the deposits were poor near the surface and probably there was a long preceding period of smaller scale work. T. A. Rickard discusses the mining of the Romans in Spain and Italy in MAN AND METALS with such care and in such detail that it is not necessary here to do more than briefly to review the more significant features of mining development.

When we do that we find that we come down almost to the Middle Ages with but little progress showing in mining, for while men made large holes in the ground they did it with a technique that was but little beyond that of a badger or a rabbit, the word for miner having such root meanings in various languages. They used hand tools to help them worry away the rock and some time in the dim past they had hit on the expedient of building a fire against the face and throwing water on it while it was hot to crack and shatter it. In Roman mining in Spain we find the first definite evidence of the use of a pick with a handle. The ore and waste were carried out of the mine on men's backs or passed from hand to hand. In the Greek mines we find parallel drifts connected by cross-cuts, and the presumption is that this was to provide for ventilation. What the Romans did about ventilation in Spain we do not know. The Greeks were practically free of

drainage problems, but there is evidence that the Romans applied some of the engineering skill they had developed in connection with their aqueducts to the drainage of their excavations. When their drifts would not drain they cut sloping channels in the walls and either baled the water up, used the screw of Archimedes, or wooden wheels almost 15 ft. in diameter; some 40 of the latter have been discovered. It is interesting to note that the axles of these wheels were bronze, not cast iron. Ladders were not used; notches were cut in the rock. It is difficult for us to realize that, in the absence of good axes and of easy transport, wood was scarce, and there was a big fine imposed on a mine contractor if he used for any other purpose wood that could be made into spears. It is amazing to think that with such means to work with the Romans could drive adits 3000 feet long and sink shafts 650 feet deep, but they did.

After Roman times about a thousand years elapsed concerning which we know little or nothing, because there is no written record. The early part of this period was principally a reversion to barbarism, but either the barbarians learned from the Romans or they knew a thing or two themselves for when we next find records to estimate progress, the most advanced mining practice seems to be in Central Europe, and it shows enormous engineering advance over the best Roman practice.

All mining engineers are so familiar with Hoover's translation of George Bauer's DE RE METALLICA that there is no need to dwell on it here at length, or to point out that it is the first systematic treatise on mining and metallurgy written by a man who really knew the industry. All earlier writers were historians, geographers, or amateur students of natural science. Bauer's book was not only printed but illustrated at the time, so we are free of much of the doubt as to the real meaning of the text that makes earlier records of so little real use to us. But even here there is some doubt, for Bauer wrote in Latin and unfortunately did not provide a glossary of local terms. The footnotes in the volume often discuss the difficulty of translation. Fortunately the pictures give us a good idea of the engineering aspects of procedure. We find horse whims used for hoisting, even elevators for the men, and a variety of pumps of the simpler sort, while ventilation problems and devices are quite fully illustrated. Ladders are used, wheelbarrows and four-wheeled cars are employed to transport material, and a great variety of improved tools are illustrated.

This treatise of Bauer's was published in 1556, over 50 years after the end of my first period, but the rate of progress was then so slow that we may take it as an accurate picture of conditions at the end of the first period. I think we may say that there was more mechanical and engineering progress in mining during the

last thousand years of this period than during the preceding 20,000 years, but even at that it had not got very far, for the rock was still fractured by fire-setting and broken away by picks. Nearly a century was still to pass before the first major improvement in mining, the use of explosives underground, was to be introduced.

The Second Period

Having used the publication of De Re Metallica, in 1556, as the end for the first period, it is necessary to go back a few years to 1492 and use the discovery of America as the beginning of the second. No real inconsistency is involved, for the first 50 years in the New World were mostly employed by the Spanish invaders in taking away from the natives the stores of gold and silver they had accumulated by centuries of work. But the Spaniards soon turned to mining and metallurgical work on their own account, their chief interest being in gold and silver. Gold continued to be won chiefly from placers, with nothing of importance in the way of improvement of methods to report, nor does there seem to be any notable progress in underground mining, except that the Spaniards practiced it more extensively and with better tools than the natives had. The silver-bearing veins of the Potosi district, Bolivia, discovered in 1544 were, until 1660, the world's principal source of supply of silver, furnishing one-third the world total of the sixteenth century. The ore was a mixture of native silver and chloride, and contained 25 to 30 per cent Ag. Metallurgical advance in the treatment of silver ores was greatly stimulated and both the equipment and the procedure were improved; one type of ore crushing equipment is still known as the Chilean mill. In 1557 Bartolome de Medina introduced the patio process at Pachuca, Mexico. This used salt and copper sulphate to convert silver sulphides into chloride, which then reacts with mercury to yield silver. It was based on earlier European practice. In 1572 Pedro Fernando de Velasco, a metallurgist, was sent out from Spain and introduced the patio process at Potosi. In 1590 Alvaro Alonso Barba, curate of the parish of San Bernando, Potosi, Bolivia, accidentally discovered, while attempting to invent a process to harden quicksilver, what is now known as the cazo, or pan amalgamation process for recovering silver. In essence it was an improved method of making the native silver and chloride react with mercury, yielding silver, though at a cost in mercury of two to two and one half times the weight of silver in the ore. It did not work on sulphides.

It would take too much space to discuss in detail metallurgical progress in Mexico and South America in the sixteenth and eighteenth centuries, but we may note in passing that the earliest methods for the recovery of metals from ores were fire methods.

Beginning about the Christian era, we find concentrated solutions of chemicals being used, but even as late as the eighteenth century solutions were often so concentrated that it would be more accurate to call them pastes rather than solutions. We are well into our third period of development before the cyanide process introduces a true dilute solution metallurgy. Anton Eilers, whom many of the older metallurgists knew in our youth, told me once that he had no liking for wet methods of metallurgy, applying the epithet "schweinerei" to them. The real trouble of course was that there were not until recently either equipment or methods available for the easy, effective, and cheap handling of solutions or their separation from solids. But difficult as it was to work with them, wet methods of metallurgical separation have been used for at least two thousand years.

The early seventeenth century introduced a profound improvement in mining operations. There is documentary proof that in 1627 Kaspar Weindl used gunpowder to blast underground in the royal mines at Schemnitz, Hungary, and a claim is made that Martin Weigel had used it at Freiberg, Saxony, as early as 1613, though it is not mentioned in a description of mining there published in 1617. It may seem curious that although gunpowder had been known for some 400 years, and had been used to blast down the walls of Pisa as early as 1403, its use in mining should be so long delayed. But we must remember that its use underground involved first drilling a hole to put it in, and no drilling had been done underground up to this time, the rock was brought down by prying at it with crowbars, striking it with a pick, or hitting it with a hammer. Like the child who found it difficult to imagine how by the aid of a stick he could rake something into his crib, miners found it difficult to imagine making a hole in the rock, charging it with gunpowder, and setting it off to break down the rock. And it was by no means easy to set off the charged hole without losing your life in the process. Trains of powder were undoubtedly first used, then crude fuses, made of goose quills or straws filled with powder, were employed, and it was not until 1831 that William Bickford, of Cornwall, patented his safety fuse that, in improved form, is still used. The use of explosives was the first considerable reduction of the human effort employed in mining. Perhaps it would be unfair to suggest that mining lagged three or four thousand years behind metallurgy in the application of inventiveness to the solution of its problems, for even Roman mining, as we have seen, involved some use of equipment, while the practice depicted by Agricola shows great advance, but even when we claim all we can for it we must still admit that seventeenth century mining exhibits but little true engineering. On

the other hand, if you read of the state of mathematics at the same period, as told by Dantzig in his book NUMBER, you need not blush for mining.

The same century was to see another great improvement that was big with future possibilities. Water had always been a great trouble, and we have seen how the Romans and later how Saxons dealt with it. Agricola illustrates a considerable number of pump designs—suction, ball and chain, and a string of buckets on a chain, worked by hand, by water power, and by horses. He describes one place at Chemnitz where water was lifted 660 feet, in three lifts, by the use of 96 horses, eight working on each pump for four hours and then resting twelve hours. This was a ball and chain pump. In Cornwall the tin mines were getting deep and water troublesome; even with the big Flemish horses, so familiar to us in connection with beer trucks, it was hard to handle it. In 1698 Thomas Savery patented what he called a water-raising engine and published in 1702 a pamphlet entitled "The Miner's Friend," that is easily recognizable as a bit of sales engineering literature for his device. Most of the credit for the steam engine ordinarily goes to James Watt, for his idea of condensing in a separate cylinder permitted the use of increased steam pressure and called for stronger metal for boiler and engine construction, but the idea of using steam to produce motion goes back as far as Hero of Alexandria, and a great many people contributed to the final achievement. It is not clear whether the need for a better source of power for pumping mines led to the development of the steam engine, or whether its developers, looking for possible applications, first turned to pumping, but at any rate mining had an intimate connection with the development of the steam engine, just as it did with alphabetic writing 3500 years earlier. Beside producing power, engines furnished a greatly increased requirement for metal as well as fuel.

Before we leave James Watt we must note that he put on a numerical basis the term horse-power as a measure of work. In trying to convince possible buyers that a steam engine could handle water, some measure of comparison with the work done by horses had to be devised and Savery had said of his engine that ten or twelve horses would be required to maintain the constant operation that his engine was capable of, though it would only raise as much as two horses could do for a brief period. Desaguliers (1763) and Smeaton (1775) had used a similar comparison. Watt's "blotting and calculation book" is still preserved and in it, under August, 1782, we find his calculation of how big a steam cylinder would be required to operate a mill to grind logwood, using 32,400 foot-pounds per minute as the rate of work of a horse, noting that the

millwright at the plant told him that a horse exerts a pull of 180 pounds while walking at the rate of 60 yards per minute. The next year we find him using 33,000, presumably as an easier figure to work with and recognizing that it was only an approximation. Apparently he later checked it by experiments made, in coöperation with Boulton, on brewers' horses. The unit is firmly embedded in our physics and engineering now, though it had such a casual origin.

We must go back now and bring up the subject of coal, that within the eighteenth century found two important uses that were destined to make it our most important mineral substance. During all the centuries that men were interested in stone and metals it had been lying about in plain sight, but nobody took any interest in it, because they usually had plenty of wood available for fuel and were accustomed to wood fires. I can find no mention of it in western literature prior to Aristotle (384–322 B.C.). Theophrastus (371–288 B.C.), who describes what is clearly bituminous coal, gives us the first clear description of it and adds that the "smell is troublesome and disagreeable." That, of course, is the reason why it was not earlier used; people used to handling a wood fire did not easily see how to burn coal successfully. The Chinese were apparently the first to use it extensively, living as they did in broad river valleys where wood was probably always scarce. Much of China is not "deforested," the alluvial plains never had any trees except a few willows along the river banks. Liu An, who died 122 B.C., refers to coal as ping-tan (ice or frozen charcoal); it is also referred to as earth (tu) or rock (shih) charcoal. Marco Polo, describing his travels in China in 1275, describes how the Chinese dig black stones out of the mountains "where it runs in veins. When lighted it burns like charcoal and retains the fire much better than wood." The use of coal was then practically unknown in the Mediterranean basin, but Rickard thinks the Romans used it in Britain although they did not in Gaul. However that may be, it is not until the thirteenth century that we begin to find frequent references to it in Western Europe, mostly in Britain. Apparently it was used as a domestic fuel and in blacksmith forges, and again we hear frequent reference to its objectionable smoke. In 1306 Parliament petitioned Edward I to prohibit the use of coal in London because of the "sulferous smoke and the savor of firing." Details as to its early use in England can be found in Chap. XIV of "MAN AND METALS." It is quite clear that men only turned to its use where wood was scarce and dear; our British cousins have scarcely yet learned how to burn it in the home without making objectionable smoke.

Up to this time all iron had been made with charcoal as fuel,

or to put it more broadly, up to the eighteenth century metallurgy, in the West at least, had depended on wood as fuel. But by this time England was making a good deal of iron and a social-economic problem developed. The nobles wanted to keep their forests uncut, as hunting preserves, while iron-making and ship-building were making considerable demands on the wood supply. In the seventeenth century Simon Sturtevant and Dud Dudley both tried making charcoal from bituminous coal without success. Efforts must have been kept up, for in 1713 Abraham Darby made a success of it, and soon thereafter the use of coke in iron-making was general in England. More than a hundred years passed before coke was used in America, though anthracite was used in our blast furnaces as early as 1833, which was before its use in Wales. We can guess what the troubles of these early experimenters were. They could not see the sulphur in the coal and did not know it was there, so it was only by accident that they finally used coal low enough in sulphur to make good pig iron. Undoubtedly they also tried to char it in the same way as wood, and it took them some time to learn how to handle it so as to get coke of the proper structure.

Let us stop for a moment to dwell on the social significance of the change to coke as a blast furnace fuel. Its significance in England was quite clear, for the shortage of the charcoal supply for even the small iron industry that existed there two hundred years ago was incontrovertible. The expansion of the British iron industry from about 20,000 tons yearly in 1741 to 500,000 yearly in 1820 and to 10,500,000 tons of pig iron in 1913 would have been quite impossible without it. I suppose you all realize that the reason why the colonists in America were allowed to begin iron-making as early as 1644 at Saugus, near Lynn, Mass., was the thought that it would be logical to make pig iron in America, where there were literally forests to burn, and send it to England as a raw material for manufacturers there. The 3500 tons of American iron that was exported to England in 1741 was one fifth of the current British output, but this economic relationship did not persist. The pig-headed colonists insisted on keeping their raw material and working it up into manufactures themselves, and there can be no doubt that this conflict of wills was one of the important causes of the Revolution; quite as important as the tax on tea, the latter being only what Woodrow Wilson would have called "an overt act." The making of brick and tile was the only manufacturing enterprise in America that preceded iron-making.

You all realize, too, that in talking about iron-making up to the end of the eighteenth century we are talking about an industry that made pig iron in little furnaces that had an output of about 25

tons a week, and that most of the iron was used as cast iron, though some of it was converted into wrought iron, with much difficulty, in fineries. Some wrought iron was also made in bloomeries, and all steel was still being made by cementation, from wrought iron, though very little of it was required, for it was not much used for anything except knives, swords, and other cutting tools.

But the advent of the nineteenth century was the beginning of a new era. The first steam engine in America was a mine pump at the Schuyler mine, near Newark, N. J., and the first steam engine built in America was constructed in the mine shop there in 1793. But good progress in engine building was being made in England, and though the attempt to use steam engines on public highways for transportation purposes was stopped by the requirement of Parliament that a man go ahead of them carrying a red flag, by the end of the first quarter of the nineteenth century we see a real beginning to railroad transportation on private rights of way.

This new development was destined to revolutionize transportation and through it the mineral industry. The railroad train could go as far in an hour as a team could in a day and could keep on going for twenty-four hours on end, instead of having to stop and rest, as a team did. And it soon proved to have a great need for iron. The engines that were being built for pumps, power, steamboats and locomotives furnished an important new market for iron, but the rails for the track were even more important. The first ones were of wood, but the use of cast-iron wheels on the engine and cars made at least a metallic face necessary on the rail. Pious people would perhaps say that when a great need develops the Lord provides a way of meeting it. But in this case it seems to have been ingenious and perhaps not very godly men who met it. The first steps had been taken by Henry Cort a generation before who, in connection with the metal needs of the British navy so improved the process of making wrought iron from pig iron in 1783 that much larger blooms could be produced with less effort but, what was more important, constructed power-driven rolls by which the blooms could be rolled out into strips. Consequently when the railroad called for long iron strips to face the wooden rails the iron plants were able to furnish them at a price that was within economic possibilities. The first rolled strips used in America were imported from England, but rolls were immediately brought over and after that we made our own. I suppose you all know that George Stephenson's first locomotive, in England, was used on the Killingworth mine railroad, near Newcastle, while the first practical one in the United States was the "Stourbridge Lion," which made a 3-mile run at Honesdale, Pa., August 8, 1929, for the Delaware and Hudson Company, so that

mining is again intimately connected with the beginnings of a development of great social importance.

But the wrought iron strips, that looked so good at first, proved to be totally unsuited for use on rails. The cast-iron wheels rolling over them so deformed their surface that they tended to curl up like shavings, with what disastrous results to the train can be easily imagined. The design was changed from a strip to heavier metal section that soon approached the modern rail section. But the wrought iron rails were too soft and a harder, stiffer metal was called for. Cast iron was too brittle, steel was too expensive, and the need was for cheap rolled steel. That however, takes us a bit beyond the end of our second period, for Henry Bessemer did not take out his patent on large scale steel-making until 1855, and we will have to leave him until later.

The steam engine created a large new market for coal, one for which it had an advantage. It had been selling for househeating purposes in competition with wood in cities where wood was dear. Benjamin Franklin had invented his improved stove in 1742, thus bettering the market for both cast iron and coal. The ruins of the old furnace that for many years devoted itself to the production of Franklin heaters can still be seen in Eastern Pennsylvania. But the steamboat and locomotive had an additional reason for using coal. Space on both of them was at a premium and the greater number of B.t.u.'s in a cubic foot of coal as compared to wood made it the preferred fuel. Boiler design therefore trended to coal-burning, and coal soon became our principal source of mechanical power. Politics had a part in it, too, for the embargo on imports from Great Britain that preceded the war of 1812 cut off imports of coal from England into our coast cities and powerfully stimulated domestic coal production. But the essential point was that man had found the way to make coal do most of his work for him, with the result that the demand for both iron and coal was greatly increased.

There was no great increase in the demand for other minerals in this period 1492–1849. Gold had been discovered in Colombia and Brazil and those two countries were the principal sources of gold for the world during the period, but there is nothing of mining or metallurgical improvement to report. Silver has already been referred to. About the only thing to be said about copper and lead was that except for brass and bullets there was not great demand for them. The Revolutionary war forced their mining in the colonies to supply our war needs, but the places from which those needs were supplied are now usually only spots of historic and geologic interest. Tin was at first used only in bronze and pewter, but in this period it found a new use that needs some discussion.

Kitchenware in the colonial period consisted chiefly of some cast-iron pots, a few knives, forks and spoons, and other miscellaneous articles. As many of them as possible were carved from wood, for metal ware was scarce and expensive. In the early eighteenth century tinware was introduced and was greatly prized by housewives.

William and Edgar Pattison, two English tinsmiths, came to Berlin, near Hartford, Conn., in 1738 and began making tinware. They bought English sheet tin at Boston, made it up into kitchenware and when they had all they could carry set out on foot peddling it from house to house. As kitchenware imported from England sold at high figures, they quickly built up their business, and soon were able to travel on horseback. Next they organized a peddling force of young men, for whom we have a modern parallel in the ones who go around selling magazine subscriptions to "put themselves through college," or the Fuller brush men. By 1790 roads began to be built and the peddlers then used wagons. Soon branch workshops were established at such places as Montreal, Albany, Richmond, and Charleston, and the peddlers worked out from all these. This was the real beginning of national distribution of domestic manufactures in America. After 1820 the increase of roads permitted a further increase of the system. The peddler often traded his tinware for farm produce and then sold that when he got to any place where he could. Finally, on reaching the frontier, he would sell his horse and wagon and make his way back on foot. Connecticut was the leading tin manufacturing state until 1850. The shop-keepers usually preferred to sell imported goods (higher price—higher profit) and refused to handle domestic wares. Peddlers were equivalent to the ten cent stores for that period. Here again we find mineral enterprise intimately associated with an important social development.

The Third Period

The third division of time for this review of mining and metallurgical history comprises the 83 years since 1850. This corresponds to something like a logarithmic scale, for the first period covered 20,000 or 30,000 years, the second 350 years, and the third only 83 years. Since the rate of progress varies inversely as the time, this seems a good basis of division.

To see at a glance what has happened since 1850, recall the situation in the United States at that time. We had an agricultural civilization that was beginning to develop strong industrial branches. The discovery of gold in California in 1848 made the country mineral-minded almost over night. Organized companies

of gold-seekers from the East and all over the world set out for California, and in the next twenty years something like three fourths of a billion dollars worth of gold was obtained by adventurers who came from all over the world. Karl Marx thought the discovery of gold in California, with the general economic upswing it produced all over the world, gave the deathblow to the German revolution in 1848. The bourgoisie and middle class gave up their political aspirations for economic advantage. I cannot dwell on the strange phenomenon that our government just let them take the gold away; that is another story that leads us into the tangled history of the development of the Federal mining law and of a mineral land policy that was to lead to a clash between developers and conservationists about 1900. Let us stick to metallurgy and mining.

The discovery of the Comstock lode has been retold so often that it is only introduced here because it created a demand for increased metallurgical knowledge. The tailings from those early mills were richer than what we would now consider rich ore. Unless an ore could be smelted in the lead furnace there was then no good low-cost way of handling it. Hours might be devoted to a discussion of the equipment and methods then used for "refractory" ores, but it is only necessary to make the point that our native Americans mostly had no background of knowledge or experience to enable them to undertake that task. We therefore had to draw on European metallurgical knowledge. Germany contributed a large part of it and any detailed review of the period 1850–1900 would introduce a large portion of German names among the men who contributed most to metallurgical progress.

Every metallurgical plant was also a training school from which people went out to exercise their skill elsewhere, while the steady succession of mineral discoveries afforded them ample opportunity to exercise such skill as they had acquired.

The Comstock is significant in another way, because it was the scene of what is perhaps the only real invention that springs from within the mining industry. The large orebodies there were a problem to men used to working veins not more than a few feet wide. Philip Deidesheimer, in 1860, at the Ophir mine, invented the square set system of timbering. This was an important contribution to mining methods based on true engineering knowledge, and it has always been a source of surprise to me that most mining men seem to attach so little significance to it. Rickard in his HISTORY OF AMERICAN MINING does not even mention Deidesheimer and makes only (page 112) a slighting reference to "ingenuity in the adaptation of European methods of timbering to unusual conditions." It is not an adaptation at all; there was nothing in

previous European experience to point to it; it was a true and significant invention by a man who was a real engineer. Deidesheimer deserves much more credit than he has ever received.

The next significant event in mining is the development of the rock drill. For nearly three centuries miners made holes in rocks for explosive charges by hand drilling before they seem to have put much really intelligent thought into trying to do it in a more efficient and economical way. Trevithick's invention of a rock-boring machine in 1813 did not develop into any practical device, and Bartlett's steam drill, used in the Mont Cenis railway tunnel forty years later, was the first really effective mechanical drill. Couch patented his percussion rock drill in the United States in 1849 but it was not until 1865 that it was put on an operative basis in the Hoosac tunnel. It seems not unfair to say that we owe the modern rock-drill mainly to the study of the problems of drilling and blasting in tunnels and surface excavations by civil engineers, not to mining engineers. When this development had gone far enough so that machines small and light enough to be practicable in mines became available, they began to be so used, and another major step in advance was taken. Hollow drill steel and a circulating current of water is the only important improvement I can think of in rock-drilling that springs directly out of mining, for the precursor of the one-man drill was the riveting hammer.

Alfred Nobel used nitroglycerine as a blasting agent in 1863 and invented dynamite in 1867. The general history of high explosives is familiar to all mining engineers and need not be repeated here. Here again we have something originally devised for another purpose finding its principal use in mining, though the time lag in this case was very short.

Going back to metallurgy, the 50 years from 1850 to 1900 was a period primarily characterized by pyrometallurgy, and only secondarily by hydrometallurgy. Such hydrometallurgy as there was, was a metallurgy of concentrated solutions and it was not until the cyanide process developed in the early 90's that we have any dilute solution metallurgy, if we except the ancient Rio Tinto process for the leaching of copper and its precipitation on iron. This latter was practiced almost without the use of mechanical equipment, whereas the cyanide process led to a tremendous development of crushing and grinding machines, filters and classifiers. This made possible much later work, not only in hydrometallurgy but also in chemical engineering. Several companies that began by building filters and other equipment for the cyanide industry later found their principal market in the sugar beet industry, in handling sewage, and in general chemical engineering. There is a temptation to make an unfavorable contrast between

mining, where equipment already developed for other uses was usually only slowly introduced underground, and metallurgy, which developed its own equipment and methods that later proved useful in other industries.

There are many interesting items we might take up, for example the substitution of rectangular water-jacketed blast furnaces for the earlier round brick furnaces. One of the greatest authorities in metallurgy 50 years ago said it could not be done because the sulphur in the charge would ruin the iron jackets. But it was done, as so much that was supposed to be impossible has been accomplished. Then followed a period of blast furnace smelting of lead and copper ores, followed by one in which the great thing in copper metallurgy was to utilize the sulphur in the ore to furnish the heat for the process. Pyrite smelting was once the great thing, although now it is almost completely forgotten.

Handling copper sulphides had always been a difficult problem. The first copper smelting was done on oxidized ores, yielding black copper and slags higher in the metal than most ores are to-day. Then the smelters got into the sulphide zone and had to go to the production of matte that was roasted and reduced. Then Manhes modified the Bessemer converter so the copper-iron matte could be oxidized to blister copper. Roasting of ores was cut down to where it would yield a matte high enough in copper for converting, while preliminary roasting was avoided by utilizing the sulphur in the blast-furnaces as a source of heat.

The working of lower and lower grade ores made it necessary to concentrate them before smelting. Putting concentrates into a blast furnace resulted in a good part of it being blown up the stack, and there was no good in putting it back again in the hope that something would eventually happen to it. Two things happened. A. S. Dwight developed his sintering machine, by which copper ore could be simultaneously oxidized and sintered on a grate, while Huntington and Haeberlein worked out a pot process for lead ores along essentially similar lines. This made the continuation of blast-furnace smelting possible, but the copper people, who had been using reverberatory furnaces for refining processes, began to adapt them for primary smelting. For a time it was a question whether it was better to sinter copper concentrate and smelt it in the blast furnace, or roast it and smelt it in the reverberatory, with the advantage apparently with the former.

An unexpected turn was given to events by the development of the flotation process. This was so effective and cheap that we can produce, through elimination of iron sulphide, a concentrate that is as rich in copper or even richer than the typical blast furnace matte used to be. As a result copper blast furnaces seem

doomed to extinction in general practice, though they will, of course, persist in certain places. This is a good example of how developments in one process normally lead to revamping of procedure all along the line. Many other examples might be cited if we had time for them.

One instance of the influence of ideas on progress: During the nineteenth century iron blast furnaces developed from little 25-ton a week furnaces to a 100-ton per day standard about 1880, responding to the demand of the Bessemer process for hot metal. Bessemer read his paper on the "Manufacture of Malleable Iron and Steel Without Fuel" before the British Association for the Advancement of Science in 1856 and his U. S. Patent was granted the same year. William Kelly and his brother had in this country been trying to make soft iron from pig iron by blowing air through it. Apparently they did not understand either the chemistry of what they were doing, or the mechanical requirements of the process well enough to bring it to an operating success, but they did delay the introduction of the Bessemer process here until 1865. Following the Bessemer converter came the open hearth furnace and many other important developments in steel production that we must pass over.

The blast furnace was able to respond to the demand for hot metal of the Bessemer converter, because, as early as 1840, Lowthian Bell had built a furnace 80 ft. high and 20 ft. in diameter at its widest part. A typical modern blast furnace is about 95 ft. high and 24 ft. in diameter at its widest part. Forgetting the influence of difference in contour (of which you will find an elaborate study in the proceedings of the Engineers' Society of Western Pennsylvania), a simple calculation will reveal that the typical furnace of to-day has a cubic capacity of less than twice that of Bell's furnace of nearly a hundred years before (1.7:1). If you ignore height and estimate capacity in terms of the largest cross-section, the ratio is still 452/251 or less than 2 to 1. But in terms of cross-section in the combustion zone the ratio is 360/50 or 7.2 to 1. Thereby hangs a tale.

During the 50 years following 1880, when blast furnaces, without much increase in size, were radically changing their shape, operating blast furnace men were chiefly worrying about the problems of lump and fine ore, hot and hotter blast and the construction of a furnace that, like the one-hoss shay, would be as strong in one part as it was in another. The story of furnace size and outline is especially well told in Boylston's IRON AND STEEL (1928) and J. C. Dovel tells the story of furnace construction in the Iron and Steel Volume of the A. I. M. E. for 1928.

In 1904 Gayley announced that by drying the blast he had in-

creased the output of a furnace from 358 to 447 tons per day, decreased the fuel from 2147 to 1726 lb. coke per ton of iron, cutting down the air requirement from 40,000 cu. ft. per minute to 34,000 and raising the temperature of the blast from 720° F. to 870° F. Obviously Gayley had done a number of things at once, but he was inclined to attach much significance to the reduction of the moisture content from 5.66 to 1.75 grains of water per cubic foot in the blast. Everybody began puzzling as to how such a cause could produce such a result, and J. E. Johnson evolved his critical temperature theory, which may be roughly paraphrased by saying that you get little steam release by heating water up to 212° F. but all the heat you put into it above the 212° level produces a corresponding release of steam. In other words, a blast furnace has to be just so hot to run at all, and the hotter it gets above that the faster it will run. This chemical speed, if that term may be used, therefore, differs greatly from mechanical speed, where power required for propulsion increases approximately as the cube of the speed.

Passing over the question as to whether Johnson's theory is sound or not, let us follow the effect of the ideas that were started fermenting by this discussion. Kinney, Joseph, and Royster of the U. S. Bureau of Mines, after the World War, engaged in a series of studies of the blast furnace based on observations on both full-sized and laboratory furnaces. There is not space here to review their findings (the chapter on chemical principles in Clement's BLAST FURNACE PRACTICE does it very well) but the final result was that they destroyed a myth of the operating blast furnace man that the rate at which his furnace can operate is governed by something that he described as the "combustibility" of the coke. If you will go back about ten years in the files of IRON AGE and other periodicals you will find a vigorous discussion about combustibility of coke. The operating men never admitted that they were wrong, or that the Bureau men were right in asserting that the rate at which coke will burn in a combustion zone is governed by the rate at which it is supplied with oxygen, but operating men eventually about doubled the number of pounds of oxygen pushed by their blowing engines into the furnace daily with the result that the furnace produced double the amount of pig iron. The iron industry, which generally believed the blast furnace had reached the limit of its practical capacity in producing 500 tons of pig iron per day, soon saw essentially the same furnaces producing 1000 tons daily. This great practical improvement resulted from a change in ideas as to how a blast furnace operates rather than from improvements in its construction and operation. As was said in the

beginning, it is more important to get a sound idea as to what can or might be done than to make empirical improvements.

If you will look up the records you will find that 50 years ago about 50,000 tons of charcoal iron was being made yearly in this country in furnaces that were not much better than Catalan forges. Perhaps the modern blast furnace, producing daily 2,000,000 pounds of fused metal containing 70,000 pounds of carbon that has to be laboriously taken out of it in an open-hearth furnace to yield steel is not the marvel of efficiency that it is regarded as being, and fifty years more may see a further advance in iron-making that will make the metallurgists of the future, who are now in the first grade in school, believe that they have lived in a period of as rapid advance as the fifty year old metallurgists of today have lived through.

Petroleum as a mineral commodity lies wholly within the third period, having developed in less than 75 years from little more than a curiosity to our second most important source of mechanical power and a production rate in the United States in 1929 of over 42 billion gallons per year. The story is so familiar that reference will only be made to some popular delusions about it. The first is that the ex-railway conductor, E. L. Drake, who was in charge of operations at the first well drilled in Pennsylvania in 1859 for the purpose of producing crude petroleum, made a tremendous contribution to the development of the industry. Of course he did nothing of the sort. The well was drilled by an experienced salt-well driller, using standard equipment. The art of well-drilling was so well known that an instructor at the School of Mines at Przibram, Austria, had published a 400-page book * on it in 1858, and the Chinese had been drilling deep salt wells for at least 500 years previously by almost identical methods. Even the idea of drilling this well for petroleum was due to G. H. Bissell, and it was no great mental achievement, since many wells previously drilled for brine had yielded considerable quantities of petroleum. H. H. Rogers erected a statue to Drake as the "founder of the petroleum industry." He should have had it cast from brass instead of bronze.

The second popular delusion is that John D. Rockefeller's activities in connection with the petroleum industry were basically inimical to the public interest. The integration and organization he brought about were actually of great benefit to the public, and the latest biography of him, GOD'S GOLD, by John T. Flynn does a good deal to correct the picture that was so distorted by the controversy over railroad rebates and the absorption of competitors. It is odd and amusing that after our long terror of monopoly the

* ERDBOHRKUNDE.

Royal Dutch-Shell group has invaded the American market, although our domestic producers have a greater capacity to supply it than is required.

After 1890 the microscope began to be used to study the structure of metallic alloys with such fruitful results that gradually every chemical and physical means possible was employed, the most recent being the use of X-rays to reveal crystal structure. Such great advances in knowledge of the nature and constitution of alloys has resulted that it has been suggested that the present be known as the alloy age. We are no longer dependent on empirical skill in making good metal, for we know now why it is good and how to control it.

One of the outstanding characteristics of this third period has been the integration of mineral producers into large corporate units, the trend in the petroleum industry in that direction being typical of the mineral industry as a whole. This has had a profound bearing on mining and metallurgical engineering. The earlier demand for engineers who had a broad knowledge of all the technology involved in a small mineral enterprise has been in large part supplanted by a demand for men who have a more intensive knowledge of some one phase of the enterprise. In a small enterprise one man often supplied all the technical knowledge of geology, mining, the use of machinery, the concentrating of the ore, and perhaps even smelting of the concentrate. Now large mining companies utilize men who have a special knowledge of geology, mechanical and electrical engineers, men who specialize in ore concentration, and metallurgists. Iron metallurgy has become so specialized that not only are there operating men and research men, but even research men who have specialized in some one part of that field. Even more than in the field of medicine the general practitioner of mining and metallurgical engineering has tended to be supplanted by the specialist. But, as in medicine, specialization is best based on sound general knowledge, and, after acquiring this, special study can be pursued in either a chosen field or one that calls the individual in the course of his experience. Many problems arise that involve knowledge of which one man possesses one part and some other man another. In executive work, especially, there is need for men with broad enough knowledge to grasp problems as a whole and effectively apply to them the knowledge of specialist subordinates. Thus there is now developing a mining and metallurgical engineering based on special knowledge instead of being the application of scientific knowledge to an empirical art.

Resume of Period III, 1848–1933

1848.	Discovery of Gold, California, made world "mineral-minded."
1855.	Bessemer process (led to open hearth, etc.).
1859.	First oil well drilled in America.
1860.	Square set timbering on Comstock.
1865.	Rock drill, Hoosac tunnel.
1867.	Dynamite.
1890.	Cyanide process, dilute solution metallurgy.
1880–1900.	America becomes a "world power" in copper metallurgy.
1850–1930.	Development of iron blast furnace and steel making processes.
1910.	The flotation process.
1900–1933.	Development of knowledge and control of alloys.
1880–1933.	Integration of mineral enterprises into large companies.
	The development of true mining and metallurgical engineering.

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HAZEN, JOHN W., Instructor in Engineering, Los Angeles Junior College, Los Angeles, Calif. D. M. Wilson, Daniel E. Whelan, Jr.

JOHNSON, THEODORE S., Professor of Industry, North Carolina State College, Raleigh, N. Car. John M. Foster, R. P. Kolb.

KIMBALL, WM. P., Instructor in Civil Engineering, Thayer School of Civil Engineering, Hanover, N. H. Frank W. Garran, F. L. Bishop.

PHELEY, DONAL B., Instructor in Engineering, Los Angeles Junior College, Los Angeles, Calif. Daniel E. Whelan, Jr., D. M. Wilson.

WALTERS, RALPH H., Instructor in Engineering, Los Angeles Junior College, Los Angeles, Calif. Daniel E. Whelan, Jr., D. M. Wilson.

BOOK REVIEW

Experimental Electrical Engineering. KARAPETOFF AND DENNISON. Fourth edition. Vol. I. John Wiley & Sons, Inc. Price $6.00.

The new fourth edition of this book covers practically the same material as the third edition. There have been no new chapters added, but most of them have been supplemented with up-to-date material and revised considerably. There are 25 chapters, and 166 laboratory tests are included in the 781 pages. The material on telephone practice and that on primary cells has been omitted.

The book is well up to the former high standard. It contains plenty of good textbook material together with the outlines for the laboratory tests. The cuts and diagrams are plentiful and well selected throughout the entire book. Laboratory courses for all engineering students requiring comprehensive written reports should find this book a very good laboratory guide.

R. C. G.

COLLEGE NOTES

University of Alabama.—Dean Geo. Jacob Davis, Jr., has been appointed State Engineer for Alabama, Public Works Administration, with headquarters at Montgomery, Alabama. Professor John M. Gallalee, Professor of Mechanical Engineering at the University of Alabama, will serve as acting dean while Dean Davis is on leave of absence.

University of Detroit.—Henry L. Coles, Ph.D., has recently joined the College of Engineering, University of Detroit, as assistant professor of chemical engineering. Dr. Coles brings with him a wide experience in industrial research and teaching. His most recent connection was as Director of the Research Institute of Wittenberg College, Springfield, Ohio. From 1922 to 1932, he directed research on metals for the Mosler Safe Company and its subsidiary, the Guardian Metals Company, of which he was vice-president. For two years, he was chief metallurgist of Niles-Bement-Pond Company. In 1918, for six months, he also served as research chemist for the Proctor and Gamble Company. His teaching record consists of work in chemical engineering at Rose Polytechnic Institute, and the College of the City of New York, besides some high-school teaching. For two years, he was a lecturer on chemical engineering at Columbia University.

Dr. Coles obtained his B.S. Degree in Chemical Engineering from Ohio State University in 1912, his Master's Degree from Rose Polytechnic Institute in 1913, and a Degree of Chemical Engineer from the same college in 1922. His Doctor's Degree was obtained at Ohio State University in 1931, his major being in chemical engineering, minor in metallurgy and metallography. He also had two years of graduate work at Columbia University which was not completed due to the fact that he left to work out the research on a commercial scale. Dr. Coles has to his credit 14 patents, with others pending. He has published numerous articles on the metal zirconium in collaboration with Dr. James R. Withrow, of Ohio State University.

Dr. Coles is a member of the American Chemical Society, the American Institute of Chemical Engineers and of Sigma Xi fraternity.

Iowa State College.—The Mississippi River Engineering Board of Review, of which Dean Anson Marston is a member, met in Vicksburg on September 1 for the purpose of submitting its re-

port on flood control to the Chief of Engineers. Dean Marston has been very actively engaged in this work and has made several trips down the Mississippi Valley this summer.

An important innovation for the Engineering Division was the transfer on July 1st of the materials and hydraulics laboratories from the Department of Civil Engineering to that of Theoretical and Applied Mechanics. The transfer was well timed with the completion of the new addition for the concrete laboratory which was requested by the C. E. Department two or three years ago. The completion of the addition, the general rearrangement of the various laboratories and in the installation of a new 20,000 lb. capacity testing machine, the building of new tables, instrument cabinets under the direction of the T. and A. M. Department, gives assurance of vast improvement in the laboratories and in the correlation of laboratory and class instruction in materials and hydraulics. The C. E. Department retains, in the building, the sanitary and highway laboratories which have recently been brought up to a high degree of efficiency. A late addition during the past summer was made to the highway laboratory in the installation of a Ro-Tap apparatus for the proper grading of highway materials.

Professor Galligan had a number of interesting projects under way during the summer. He was employed as consultant by Howard R. Green Company, consulting engineers of Cedar Rapids, on the preliminary investigations and final design for sewage treatment of the city of Cedar Rapids. He was also employed by the U. S. Department of Agriculture and designed and supervised the construction of a plant for the production of gas from cornstalks on a small farm near Ames. The objective of this work was to provide a unit in which a farmer might produce gas from cornstalks or stable bedding in quantities that would furnish gas for lighting, cooking and operating small power machinery on the farm. He and Vincent M. Roach, a last year's graduate in civil engineering, also developed a process for the removal of iron from water supplies under pressure. An experimental plant was built and operated in connection with one of the wells of the City of Ames during the summer and considerable interest was aroused as was evidenced by visits to the Ames plant from town councils to observe the operation of this experimental plant.

Professor M. P. Cleghorn has been having an interesting and worthwhile summer in the East, the chief objective of the trip being to take part in steam turbine tests at Lynn, Massachusetts.

Professors Fuller and Kerekes have recently executed a contract with D. Van Nostrand Company, New York Publishers, for taking over the remaining copies of their "Analysis and Design of Steel Structures," which was published in January, 1933, by the

Tribune Publishing Company of Ames, and for issuing a revised edition as early as practicable. The book will be used in at least two other colleges beginning with the Fall quarter.

University of Maine.—Mr. Bernard Franklin Parr, Instructor of Mechanical Engineering, resigned during the summer to resume a position in design engineering at the Westinghouse Electric and Manufacturing Company. He is located at the company's plant at Mansfield, Ohio, and may be addressed at 47 Lexington Avenue, Mansfield, Ohio.

Mr. Horace Elmer Hall has been appointed Instructor of Mechanical Engineering at the University of Maine. Mr. Hall received a B.S. in Mechanical Engineering from the State College of Washington in 1928; M.S. from the University of Pittsburgh in 1930; and has done graduate work at the Massachusetts Institute of Technology. He also completed the design school course of the Westinghouse Electric and Manufacturing Company.

University of Southern California.—After two years of decreasing enrollments the College of Engineering this year experienced a slight gain, principally on account of a larger freshman registration and partly due to the influx of a greater number of junior college students to the junior year. The number of graduate students dropped about fifty per cent. This experience would seem to indicate a healthy trend toward improved business conditions in Southern California.

Perhaps the most important part of this report, however, is the success of recent engineering graduates in finding engineering connections. The class of 1931 had very good success in finding positions after graduation, perhaps three quarters of them. In 1932, however, only about one quarter of the graduating class found engineering work, many of them becoming clerks in grocery stores, or anything to provide some kind of living. Early last summer, however, for the first time in several years calls began to come to the University for young engineers. By the middle of August it was found that, for the classes of 1932 and 1933, about sixty per cent were in engineering or related work, in addition to connections made by older graduates. Since August many more young engineers have been placed and the indications are that by winter time employment among our younger graduates will be almost if not quite normal.

Professor Thomas T. Eyre, Chairman of the Department of Mechanical Engineering, is on sabbatical leave for the first semester 1933–34, in Europe, observing conditions on the other side. He will return with his family in January.

University of Texas.—The new engineering building is the largest of the group of nine new buildings recently completed on the University of Texas Campus. It covers an area about 390 feet long by 288 feet wide. In the center of the building there is a court 200 feet long and 55 feet wide. The ground area actually covered by the building is approximately 100,000 square feet. All of the departments of Engineering are housed in this new structure with the exception of Architecture. Physics, Chemistry and Architecture have new buildings of their own.

In planning this new home for the College of Engineering it was necessary to design a building which would include a one-story laboratory structure 320 feet long and 140 feet wide completed some four years ago, in which the departments of Mechanical and Electrical Engineering have been housed. The new building was erected in U-shape around the old structure, in such a manner as to make the old part the rear of the building, enclosing the rectangular court mentioned above. A loggia around three sides of the court aids in binding the two structures into a unit. The building is reinforced concrete and steel, faced with brick and stone. The roof is of red tile. An idea of the appearance of the structure can be obtained from the accompanying picture, although this shows little of the laboratory space.

The main front portion of the building is three stories in height. Here the engineering library, the offices of the staff, the drafting rooms, and most of the classrooms are located. Several classrooms are provided with artificial ventilation and darkening shades for lantern use. In general the wings and rear of the building are devoted to laboratories: the east side to Civil Engineering; the rear (north side) to Mechanical Engineering and Electrical Engineering; and the west side to Petroleum Production Engineering and additional electrical space. Large window spaces are provided in these new wings giving excellent natural light for all of these laboratories.

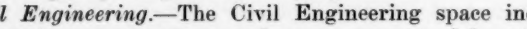
Drawing and Design.—The Department of Drawing is located on the third floor of the front portion. Three drafting rooms, each accommodating forty students, occupy the north side where an entire wall of factory type sash provides natural light. Electric ceiling fans are provided. New drafting tables have been installed in one room, each table providing an individual board compartment and instrument drawer for the students of four different sections. A departmental drafting room and a model room are also located on this floor.

The blueprint room is in the attic of the building. The equipment consists of a sun frame on a track which extends out onto the roof of the building, an electric blueprint machine equipped with a modern high-speed lamp, and two washing vats.

On the north side of the second floor are three drafting rooms similar to those above, each accommodating thirty-six students. These are assigned to machine design, structural design and one jointly to highway design and surveying classes.

Civil Engineering.—The Civil Engineering space includes a surveying instrument room and seven separate laboratories assigned respectively to materials testing, cement and concrete, hydraulics, sanitary engineering, asphalt, road stone, and soils testing.

The materials testing laboratory is about 45 ft. by 55 ft. and houses the present equipment, the largest of which is a 400,000 lb.



Riehle compression machine. It also provides space for future equipment. The present supply of accessories, such as gauges and the like, is being considerably augmented.

The cement and concrete laboratory, slightly larger than the materials laboratory, has a monorail for transporting test specimens to the testing machines. A 10 ft. by 15 ft. moist storage room is provided. This is concrete lined and shelved and equipped with the Carrier system of temperature and moisture control so as to maintain a constant temperature of 70° and a relative humidity of 100%. Other equipment is sufficient to provide for classes of about twenty in the routine type of tests.

The hydraulics laboratory is on two levels, a lower floor 81 ft. by 35 ft. over about two thirds of which is a mezzanine floor. Wier boxes and orifices, pipe runs for friction loss tests, water turbine, hydraulic ram, Pitot tube connections, in fact all equipment requiring measurement of discharge rates is located on the mezzanine floor; while weighing tanks, scales, supply pumps and other accessories are on the lower floor. A tank, extending through both stories and equipped with overflow wiers, provides a constant static head of 28 feet for varying discharge rates. Space is reserved for model tests and future demonstration table.

The sanitary engineering laboratory is for research work by

advanced students, but the present equipment is limited. No routine laboratory work is now planned.

The highway laboratory space consists of three rooms and storage. The stone laboratory 27 ft. by 60 ft. (including storage) is equipped for the usual tests on road stones. The asphalt laboratory 27 ft. by 32 ft., is equipped for the standard tests on asphalts. Hoods connected to suction fans will remove the objectionable fumes. The soils laboratory, 28 ft. by 36 ft., will be equipped to make the tests recommended by the U. S. Bureau of Public Roads for classifying soils into types A1 to A8. The equipment for this laboratory is entirely new.

Mechanical Engineering.—The Mechanical Engineering laboratories are in a 140 ft. by 240 ft. section of the older laboratory structure. The heat power laboratory contains automobile, kerosene, natural gas, full and semi-diesel two and four stroke internal combustion engines; simple and compound steam engines of various types with condensing apparatus; impulse type steam turbines; rotary, centrifugal and reciprocating pumps and compressors; an ammonia compression type refrigerating plant; a vertical, natural gas fired steam power boiler and a house heating boiler; fluid flow and heat exchanging apparatus; and a well selected line of engine indicators, tachometers, etc., necessary for the testing and studying of these units. Most of the high speed engines and pumps are equipped with cradle dynamometers while the low speed engines are fitted with Prony and rope brakes. Fuel calorimeters are available for testing the fuels used by the gas and oil engines, and a friction testing machine and smaller apparatus are available for a study of the lubricants.

The shop laboratory is equipped with wood lathes, etc., for pattern making; with a cast iron cupola and soft metal crucibles in a foundry room for foundry practice; with forges, electric and gas welding equipment, electric and gas fired heat treating furnaces, and the necessary microscopes and hardness testers for metallurgical study; and with engine and turret lathes, milling machines, shapers, planers, radial drills, etc., for machine shop practice.

Electrical Engineering.—The main Electrical Engineering Laboratory, formerly used for all purposes, has twenty blocks, each of which supports two machines with the necessary auxiliaries. In this room there are seven distribution panels and a main panel. The main panel is connected to each of the other laboratories through trunk lines and branch lines from a.c. and d.c. sources. West of the main laboratory are the shop and instrument room, store room, and photometric laboratory. The photometric laboratory has two integrating spheres, bar photometer, flicker photom-

eter, Weber photometer, and other adjuncts. The illumination laboratory is in the form of a classroom with six demonstration lighting fixtures from which thirty-five different effects can be obtained. There is also in this room a 21 kw. cove installation with four color circuits which are controlled by resistance dimmers and an automatic Thyratron dimmer.

West of the shop and illumination laboratory is the two story section. On the ground floor of this portion are the standards laboratory, a display room, and a sophomore laboratory. The standards laboratory contains standardizing apparatus build about a nucleus consisting of a Kelvin balance, a standard watt-meter, volt-meter, and ammeter, and a second-beat clock. This apparatus is permanently connected for immediate use to check the laboratory meters. The display room is used to show typical pieces of apparatus, such as insulator strings, transmission line conductors, air break switches and high voltage fuses; also for the laboratory study of power transmission circuits. There is also a watt-hour meter display arranged in the order of historical development, a relay test and demonstration board, and a network short-circuit test board.

The sophomore laboratory, as well as the other laboratories in this part of the building, has, as a special feature, a three conduit asbestos board duct along the wall at the back of the tables. The front face of this duct can be removed at any point, thereby making available all of the circuits at any point. On the second floor of the west portion of the building is the electric circuit or junior laboratory, a computing and consultation room, and a telephone laboratory.

The telephone laboratory is completely equipped, having as a nucleus an artificial transmission line with measuring apparatus, a common battery local, a seven-position multiple switch board, a local test board, a complete toll test board, and certain special automatic switches of the Stowger type. There are also the usual auxiliaries common to a modern central telephone office.

Petroleum Production Engineering.—The Department of Petroleum Production Engineering is to occupy three rooms in the west wing, consisting of a large laboratory equipped for students' use and two research laboratories.

The large room is equipped with laboratory tables, each served with gas, compressed air, electric connections and water. This laboratory is equipped for undergraduate experiments of a general rather than advanced type. These consist of such exercises as measuring viscosities of oils and of rotary drilling muds; specific gravity determinations by the different methods used in the laboratories and in the field, the measurement of deviation from the verti-

cal of an oil well; methods of separating oil and water; the study of oil-well cements; and oil migration problems.

The research laboratories are equipped for the more advanced work, having hoods, microscope tables, balance tables, and a constant temperature bath in addition to the table connections such as used in the undergraduate laboratory. They are equipped with specially built apparatus for determining the viscosities of mud; for the rapid analysis of oil field waters; for determining the plastering effect of mud fluid on oil sands of various characters; for determining the effective porosity of oil sands and comparing the several methods of determination. There is also high pressure apparatus, by which it is possible to imitate original pressure conditions in an oil reservoir.

The apparatus for the determination of the viscosity of drilling mud, of original design, is based upon the rate of fall of a metal dart or steel ball through a vertical tube of thoroughly mixed mud.

Equipment has been designed to determine the plastering effect of drilling mud in an effort to give notice of the possibility of plastering off a productive oil strata. The apparatus utilizes a pressure range up to 1500 pounds per square inch.

At least three types of apparatus will be used for the determination of the porosity of oil producing sands: a recent design of "Hydrogen Porosimeter" which has been altered slightly in the method of construction, and made of monel metal; the apparatus used by most oil companies, utilizing the Russell volumetric flask, commonly called the "acetylene tetrachloride" flask; and a mercury porosimeter of slightly different design, also constructed of monel metal.

A miniature oil reservoir, specially equipped with high-pressure air, is provided for the study of relative ultimate recoveries by the various methods of oil production. The pressure box is constructed of heavy steel plate, and is equipped with valves and pressure gauges permitting as many variations in pressure and flow of oil as may be desired.

ERRATA

JOURNAL OF ENGINEERING EDUCATION, Vol. XXIV, No. 1, September, 1933, page 80, tenth line from the bottom of the page, the name spelled "Lyle" should be "Lyell."

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Engineering Communications: There is evidence that engineers and teachers of engineering are thinking seriously about methods used to convey ideas.

"The young graduate engineer should certainly know the language of his profession and should be able to make, read and interpret drawings without the slightest difficulty" (*Machinery*, August, 1933).

"Such (engineering) reports consist of written descriptive matter supplemented by specifications. In either case the inference is that to make a successful report the engineer must have fluent command of both the English language and the graphic language, . . ." (Prof. Thos. E. French, S. P. E. E., 1933).

". . . the question of the medium of communication must be settled. English is, of course, one such means, but it is not the only one available. A report may conceivably have no running text at all; the material may be presented wholly by graphs or tables, displayed in a clear and orderly fashion . . ." (Prof. J. Raleigh Nelson, S. P. E. E., 1933).

"If I have one quarrel with the engineering institutions today, it is because they turn out their students year after year, many of them lacking in that first fundamental of an educated man, the ability to write and speak his own language effectively" (Ralph Leavensworth, S. P. E. E., 1933).

"His own language!" Is it not compounded of drawing, of writing, of speaking? Engineering drawing, Engineering English, Engineering speech? Drawing alone, writing alone, speaking alone are not enough. All three are media of importance, but how to make use of all three in a related and effective style needs more attention.

Can not some educational genius find better words to describe this type of communication? Indeed, can not some engineering college administrator blaze a trail to show the way of combining all of these important and essential elements of the recording and transferring of ideas into one coördinated course of study which will train engineering students effectively to record, to convey, and to present engineering information?

PROGRAM OF THE SECOND ANNUAL MEETING OF THE PACIFIC SOUTHWEST SECTION OF THE SOCIETY

UNIVERSITY OF SOUTHERN CALIFORNIA, LOS ANGELES, CALIFORNIA, DECEMBER 28, 29, 30, 1933

Officers of the Section.—Chairman, H. B. Langille, University of California; Vice-Chairman, D. M. Wilson, University of Southern California; Secretary-Treasurer, F. O. Rose, Modesto Junior College.

THURSDAY, DECEMBER 28, 1933

9:30 A.M. *First Session:* H. B. Langille, presiding. "The Functions of an Engineering Advisory Council," Philip S. Biegler, University of Southern California; "A Study of Engineering Education from the Viewpoint of the Employer of Engineers in Southern California," David M. Wilson, University of Southern California; "Engineering Courses as Viewed by a Graduate Student," R. B. Vaile, California Institute of Technology; "Public Speaking and the Pursuit of Culture," Dr. B. M. Woods, University of California.

2:00 P.M. *Second Session:* H. B. Langille, presiding. Address of Welcome, Dr. F. C. Touton, Vice-President, University of Southern California; "Wastes in Education," F. H. Sibley, University of Nevada.

3:30 P.M. Visit to Edward L. Doheny, Jr., Library, and points of interest on the campus of the University of Southern California. A short talk pertaining to the library will immediately precede the visit.

FRIDAY, DECEMBER 29, 1933

9:30 A.M. *Third Session:* Presiding officer to be announced. "The History of Engineering Education in the Junior Colleges of California," Franklin O. Rose, Modesto Junior College; "Aims and Objectives of Semi-Professional Engineering Courses at Los Angeles Junior College," R. H. Walters, Los Angeles Junior College; "Lower Division and Completion Engineering Courses in the Smaller Junior Colleges," Arthur C. Terrill, Fullerton District Junior College; "Problems of the Thirteenth Year Engineering Curriculum," Arthur C. Gehrig, Pasadena Junior College; R. E. Davis, University of California, will lead the discussion.

1:30 P.M. Visit to Movie Studio, for members and their ladies.

6:30 P.M. Informal reception and dinner for members and their ladies. Address: "William Morris, Engineering, and the Culture of the World," Dr. Edwin Diller Starbuck, University of Southern California.

SATURDAY, DECEMBER 30, 1933

9:30 A.M. *Fourth Session:* H. B. Langille, presiding. Transaction of business; election of officers. "Mathematics Requirements for Graduate Work in Engineering at California Institute of Technology," Dr. S. S. Mackeown, California Institute of Technology; "Classification of Engineers," A. B. Domonoske, Stanford University.

GENERAL

All members are requested to register as soon as convenient after arrival.

Campus headquarters of the Section will be found in the Student Union Building, 36th Street and University Avenue, Los Angeles.

Mail and telegrams should be addressed to the College of Engineering, University of Southern California, Los Angeles, California.

Please make reservations for the dinner, and the trip to the Movie Studio, at the time of registration. Statements on the return postal cards sent out with the programs will aid the committee in making arrangements.

COMMITTEES

Program: D. M. Wilson, Chairman, University of Southern California; A. B. Domonoske, Stanford University; R. W. Sorensen, California Institute of Technology.

Junior Colleges: D. E. Whelan, Jr., Chairman, Loyola University; R. E. Davis, University of California; H. H. Bliss, Riverside Junior College; A. C. Terrill, Fullerton District Junior College; A. G. Gehrig, Pasadena Junior College.

Arrangements: P. S. Biegler, Chairman, University of Southern California; R. M. Fox, University of Southern California; C. E. Guse, Los Angeles Junior College; T. T. Eyre, University of Southern California; Franklin Thomas, California Institute of Technology.